CHAPTER XVIII

INJURIES OF THE SHOULDER

Surgeons who take anxious steps to prevent stiffness of the injured shoulder by early movement, passive stretching and repeated manipulation make the joint still more stiff by their worrying treatment. Movements too early, passive movements too vigorous, and manipulations too often, are the commonest causes of stiffness—and yet the fear that prompts such treatment is unfounded. There is no danger in immobilising a dislocated shoulder for three or four weeks even in elderly patients; full movement will be regained if active exercise is relied upon to the exclusion of passive force. The only danger is that failure to immobilise may cause recurrent dislocation exactly as it does in every other joint. Many healthy young men have been disabled by recurrent dislocation of the shoulder through neglect to immobilise the first dislocation—a neglect that is foolish in healthy young men.

Moreover, there is no greater danger of permanent stiffness when a shoulder is immobilised by the side than when it is immobilised in abduction; it is no more difficult to regain abduction movement when the limb has been in a sling than to regain adduction movement when it has been in a frame. Much nonsense has been talked about the effects of gravity on stiffness of joints. The elbow that is stiff in extension can be mobilised just as surely as the elbow stiff in flexion; the ankle stiff in equinus can be mobilised no less certainly than the ankle stiff in any other position; the stiff knee, stiff hip, stiff back and stiff neck are mobilised not by gravity but by active exercise. Let there be no fear of immobilising an injured shoulder with the limb by the side of the trunk.

In one respect the shoulder differs materially from other joints. The rotator cuff, which includes the tendons of infraspinatus, supraspinatus and subscapularis fused intimately with the capsule of the joint, is exposed to unusual wear and often shows traumatic degeneration. This fibrotendinous cuff impinges against the acromion and the acromio-clavicular joint with every abduction movement of the limb, or at least it would do so without the protection of the subdeltoid bursa (Fig. 710). The bursa, which is sometimes separated into two parts, the subacromial and subcoracoid, lies between the head of the humerus and the arch formed by the acromion, acromio-clavicular joint and coraco-acromial ligament. With increasing age and hard physical effort the bursal protection may become inadequate, especially if the acromion is thickened or if there is arthritis of the acromio-clavicular joint with osteophytes on its inferior aspect. Supraspinatus tendinitis then develops, occasionally with calcification, sometimes with almost spontaneous rupture of the degenerated fibres, and often with periarthritis and periarticular adhesions causing limitation of abduction and external rotation.

Such degenerative changes occur even when there has been no specific injury [1] but they may also complicate fractures or dislocations of the joint and cause greater difficulty in preventing stiffness Nevertheless, even degeneration of the capsule and rotator cuff with its predisposition to adhesion formation does not condone early mobilisation, passive stretching or repeated manipulation indeed the danger is more real and the importance of active exercise without passive force is still greater

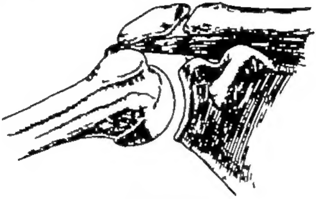

FIG 710

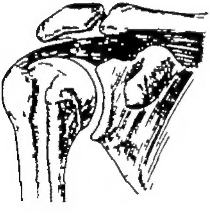

FIG 711

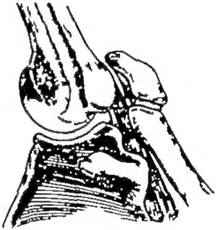

FIG 712

The supraspinatus tendon is impinged upon by the acromion in the middle range of abduction but not when the humerus is by the side nor when it is in full abduction.

DEGENERATIONS OF THE ROTATOR CUFF OF THE SHOULDER—SUPRASPINATUS TENDINITIS

The progressive degeneration that causes tendinitis and leads ultimately to spontaneous rupture of the musculo-tendinous cuff and sometimes of the long tendon of biceps is illustrated in the radiographs of a seventy three year old patient (Figs 713-715) In 1945 at a time when radiographs showed early arthritis of the acromio-clavicular joint and slight sclerosis of the tuberosity of the humerus there was clinical evidence of supraspinatus tendinitis Friction of the tendon against the acromion, and osteophytes below the acromio-clavicular joint caused pain in the middle third of abduction movement (Fig 713) Two years later the changes were more advanced and there was periarthritis with adhesions limiting abduction and

[1] Harrison S. H "Painful Shoulder Significance of Radiographic Changes in Upper End of Humerus." *J Bone Joint Surg* 1949 31-B, 418.

FRACTURES
AND JOINT INJURIES

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Fig 713
Radiograph in 1945

Fig 714
Radiograph in 1947

Fig 715
Radiograph in 1949

Progressive degeneration and finally spontaneous rupture of the rotator tendinous cuff and long tendon of biceps

Evidence of supraspinatus tendinitis developed in this patient in 1945 radiographs then showed early sclerosis of the tuberosity and arthritis of the acromio-clavicular joint (Fig 713). Two years later the changes were more advanced and there was clinical evidence of periarthritis with adhesions (Fig 714) By 1949 there was much more sclerosis and irregularity of the tuberosity and adjacent part of the humeral head, and there had been spontaneous rupture of the whole rotator cuff (infraspinatus, supraspinatus and subscapularis) as well as of the long head of the biceps.

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external rotation movement but there was not yet loss of power (Fig 714) By 1940 sclerosis of bone and irregularity of the tuberosity were much increased and suddenly one day without recognised injury there was complete rupture of the rotator cuff with inability to abduct the limb and also spontaneous rupture of the biceps tendon with retraction of the muscle to the lower arm (Fig 715) Continued wearing of the tendinous cuff against bone had first caused supraspinatus tendinitis then periarthritis with adhesions and finally spontaneous rupture of the tendons

Supraspinatus tendinitis[1-4]—The patient complains of pain in the middle third of the arc of abduction movement from about 70 to 120 degrees—the range through which the tender area impinges against the acromion When the painful arc is passed and the limb is in full abduction movement is again painless but as the limb is brought down to the side there is sharp pain from 120 to 70 degrees of abduction Movement is not limited in any direction as it is in arthritis or in periarthritis with adhesions Moreover it is painful only in the middle third of the range of abduction whereas in arthritis all movements are painful from the beginning and in periarthritis with adhesions movements are painful beyond 90 degrees and increasingly painful as movement continues—there is no painless range at the limit of abduction

The differentiation of simple supraspinatus tendinitis from early rupture of the tendon where again there is a painful arc of movement in the middle third of abduction is often difficult and sometimes can be determined only after surgical exploration[5-6] In general however when there is no loss of power and no recourse to trick movements with curious rotatory twists as the limb is raised or lowered the diagnosis of simple tendinitis can be relied upon

The symptoms often disappear after simple rest Recovery may be accelerated by injecting about 10 c c of 1 per cent novocaine[7 9] Immediate relief of pain is dramatic but the patient should be warned that it may recur within a few hours and even be intensified The pain then subsides and recovery is usually complete In the few cases in which tendinitis with pain is persistent or recurrent excision of the acromion is indicated (see page 454)

Supraspinatus tendinitis with calcification—The degenerative change of supraspinatus tendinitis like that of any other relatively avascular fibrous tissue is often associated with a deposit of calcium salts—an amorphous mass of calcium carbonate and phosphate in semi fluid state resembling toothpaste (Fig 716) Such calcification is seen in old fibrosed tuberculous glands the organised clots of varicose veins and hæmangiomata the walls of sclerotic arteries and the fibrous layers of costal cartilages It is seen especially in degenerated tendons—the tendo Achillis many years after it has been tenotomised the gluteal tendons at their insertion to the trochanter the pyriformis tendon the common extensor tendon at the elbow the

Codman, E. A. *Surg Gynec Obstet*, 1931 52, 579.
Codman, E. A. "The Shoulder" Boston Thos. Todd Co., 1934
Meyer A W *Arch Surg* 1937 35, 646.
Keyes E L *J Bone Joint Surg* 1935, 17 953.
Brown J T "Early Assessment of Supraspinatus Tears Procaine Infiltration as a Guide to Treatment." *J Bone Joint Surg* 1949 31-B, 423
Ellis, V H Paper to Joint Meeting of Orthopædic Associations in London, 1952, advocating novocaine infiltration and also arthrography in diagnosis of early tears.
Haldeman K O and Soto-Hall, R *J Amer med Ass*. 1935, 104 2319
Haggart G E, and Allen, H A. *Surg Clin N Amer* 1935, 15, 1537
It may be still better to use xylocaine which causes less reaction.

subscapularis in front of the shoulder and most common of all the supraspinatus tendon beneath the acromion[1 2]

The symptoms resemble those of uncomplicated tendinitis but the volume of calcium deposit so increases impingement against the acromion that the pain is much more severe It is sometimes agonising and the patient may refuse to attempt abduction movement beyond 60 or 70 degrees One patient was comfortable only when she sat with the limb hanging by her side, dependent from the shoulder—she could not tolerate even the support of a sling In such cases pain may be referred beyond the deltoid insertion to the forearm and hand and sometimes to the scapular and occipital regions[3] The pain often subsides after simple bed rest and the calcareous deposit may disappear,[4] but large deposits cause pain so severe that continued expectant treatment is not justified Evacuation of the deposit through wide bored aspirating needles has been attempted[5] but it is better to make a short incision split the fibres of the deltoid and remove the grey yellow paste with a small curetting spoon

Fig 716
Calcification of the supraspinatus tendon.

Supraspinatus tendinitis with ossification—It is known that calcified tendons may become ossified—as may any mass of pathological calcification This is probably the cause of heterotopic ossification of the tendo Achillis[6] So far as I am aware ossification of the supraspinatus tendon and rotator cuff of the shoulder has not been reported except in the patient recorded in earlier editions of this book but exceptional as that case may have been it was important because it encouraged me to excise the acromion process—an operation that has proved to have wide application[7] Eight years before a calcareous mass had been removed through a short incision and relief of symptoms had been complete There was then recurrence of severe pain especially when the limb was abducted from 60 to 120 degrees and radiographs showed extensive ossification of the whole rotator cuff of the shoulder (Fig 717) Clearly this mass could not be excised without destroying the abductor mechanism of the joint—but the pain from impingement could be relieved by excision of the acromion It was interesting to find that the patient regarded this as a minor operation

Watson-Jones, R. and Roberts, R. E. *Brit. J Surg.*, 1943 31 461.
Hamilton, A. R. *J Bone Joint Surg* 1951 33-B, 573.
Moseley showed that in a normal individual, injection of less than 1 c.c. of 5 per cent. saline into the supraspinatus tendon caused pain referred to the deltoid insertion and that as the volume of injected fluid was increased the field of pain radiation was greater until it resembled "brachial neuritis" with pain from the occiput to the fingers. *Canad med J.*, 1942, 46, 161.
Jones, G Blundell. "Calcification of the Supraspinatus Tendon." *J Bone Joint Surg* 1949 31 B, 433.
Patterson, R. L. and Darrach, W *J Bone Joint Surg.*, 1937 19, 993
Watson-Jones, R., and Roberts, R. E. "Calcification Decalcification, Ossification" *Brit. J Surg.*, 1934 21 461.
Excision of the acromion—I think that I was the first to suggest this operation but of course one never knows it is difficult to believe that any procedure so obvious had not been done before. I reported it to the British Orthopaedic Association in 1939 It was referred to by A. Steindler in 1944 in the treatment of ruptures of the supraspinatus tendon (*J Iowa State med. Soc.*, April, 1944) It has been used by M. N Smith-Petersen in certain cases of rheumatoid arthritis and it was described in detail by J R. Armstrong in 1947 ("The Supraspinatus Syndrome" *Lancet* 1947 1, 94) and again in 1949 ("Excision of the Acromion in Treatment of the Supraspinatus Syndrome. Report of Ninety five Excisions. *J Bone Joint Surg* 1949 31-B, 436) H F Moseley illustrated the operation in diagrams in 1951 but without comment on the merits and without reference to the literature ("Ruptures of the Rotator Cuff," *Brit. J Surg.*, 1951, 38, 350).

PART IV

INJURIES OF THE LOWER LIMB

FIG. 717

FIG. 718

Ossification of the rotator cuff developing eight years after an operation for calcification of the tendons. There was severe pain in the middle third of the arc of abduction from impingement against the acromion (Fig. 717). Excision of the acromion relieved all symptoms and despite the mass of bone in the tendons the patient was able to do heavy work without discomfort and has been free of symptoms for ten years (Fig. 718).

in comparison with the earlier procedure which to me had seemed trivial because recovery of movement after the second operation was so painless. Within a few weeks he had normal movement and within a year he salvaged furniture from a bombed house and lifted wardrobes and dressing tables without difficulty.

Excision of the acromion—There is obvious merit in this operation for any degeneration or injury of the rotator cuff produced or aggravated by impingement against the acromion. It is not surprising that even the whole acromion can be excised without functional or cosmetic loss because scapulo-clavicular stability depends essentially on the coraco-clavicular and not the acromio-clavicular ligaments, and moreover such fibres of the deltoid as are reflected can easily be stitched back. It is better to remove the whole acromion right up to the joint and not just part of it. The surgeon should take the anæsthetist's position and look down on the acromion which is exposed subperiosteally through a three inch incision. The acromio-clavicular ligaments are cut, the bone is divided obliquely with a thin osteotome and the deltoid is stitched back to the reflected periosteum. It is very easy and satisfactory, and is indeed the complete answer to problems of recurrent and persistent supraspinatus tendinitis with or without calcification. I believe also that it is an essential part of the operative exposure of ruptures of the tendon and an important measure in accelerating recovery after that operation (Figs 722, 723).

INJURIES OF THE ROTATOR CUFF OF THE SHOULDER—RUPTURES OF THE SUPRASPINATUS

In former years insult was often added to injury when patients sustained ruptures of the rotator cuff of the shoulder—they were nearly all charged with malingering. This is perhaps not surprising because the injury was often trivial, and the somewhat remarkable physical signs were not understood. Being asked to raise his arm the patient would puff and struggle and go red in the face but still fail to elevate the limb beyond the right angle, whereas when the surgeon first raised it for him he would easily hold it in any required degree of abduction. That in itself did not seem genuine. When the patient complained of pain half way through the movement and no longer complained when movement was pressed still further, the unknowing surgeon's doubt was increased. And when finally the patient indulged in extraordinary antics, twisting and rotating the limb in a curious way as he raised and lowered it, even bending his trunk right over to one side in a manner that seemed unreal and demonstrative, the surgeon's worst fears were confirmed—the man was malingering. Such was the diagnosis in nearly every case. We owe a great debt to Codman of Boston for his studies of the shoulder.[1] He explained the reality of these curious apparently unconvincing signs and not only saved many labouring men from unjust charges but showed us how to treat their tendon injuries.

Clinical features of complete rupture of the rotator cuff—The patient is often a middle-aged labouring man who has worked hard all his life. The injury that precipitates the onset of symptoms is usually no more than a strain such as supporting a heavy weight with the abducted arm or throwing out the limb to protect himself against a fall. Long continued heavy work having caused attrition of the tendons, simple strain causes final rupture. Sometimes the rupture is a complication of dislocation of the shoulder[2-4] but on the other hand there may be no recognised injury at all.

[1] Codman, E. A. The shoulder. Boston: Thos. Todd Co., 1934.
[2] Greeley, P. W. and Magnuson, P. B. J. Amer. med. Ass., 1934, 102, 1835.
[3] Bosworth, D. M. J. Bone Joint Surg., 1940, 22, 369.
[4] Watson-Jones, R. Brit. med. J., 1936, 2, 60.

Massive rupture of the supraspinatus and infraspinatus tendons gives rise to typical loss of power : active abduction is more limited than passive abduction despite vigorous contraction of the deltoid the limb cannot be abducted against resistance—even the resistance of gravity but if it is first raised passively or if the resistance of gravity is evaded by trick movement such as bending the trunk to the opposite side the limb can then be held in the elevated position This is because the humerus cannot be abducted by the deltoid alone The supraspinatus is an essential synergist with function like that of a builder's mate who stands with one foot on the

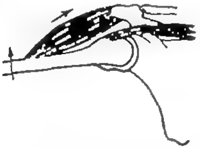


Fig 719

Fig 720

The function of the supraspinatus is to fix the head of the humerus while the deltoid abducts the arm (Fig 719) If the tendon is ruptured or avulsed, only weak abduction to 60 degrees by scapular movement is possible (Fig 720)

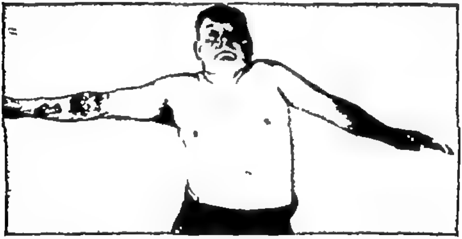


Fig 721

Rupture of the supraspinatus tendon of the left shoulder (complicating a dislocation of the joint).

bottom rung of a ladder to fix it while it is being raised The supraspinatus fixes the head of the humerus to the glenoid to provide a fulcrum for the deltoid (Figs 719-720) and if there is no such fixation strong contraction of the deltoid merely pulls the humerus up towards the acromion and holds it there while the scapula rotates In this way weak abduction to 60 or 70 degrees is possible the more the patient struggles to elevate the arm the more he shrugs the shoulder (Fig 721) The analogy between the supraspinatus and the builder's mate is very close because in the same way that when a ladder is once raised the workman need no longer stand on the bottom rung so when the arm is first raised passively by an examiner it can often be held elevated by the deltoid even when the supraspinatus tendon is ruptured

PART III

INJURIES OF THE UPPER LIMB

Clinical features of incomplete rupture of the rotator cuff—Less massive tears of the rotator cuff cause equivocal signs and incomplete ruptures may present no more than the clinical features of supraspinatus tendinitis Active abduction is often possible through a normal range, but the movement cannot be performed against resistance, and there is pain in the middle third of the arc of abduction To escape this pain, which arises from impingement against the acromium of the torn and therefore thickened capsular margin the patient may raise and lower the limb by a curious circumduction—the arm being so rotated as to minimise the friction There is also reversal of scapulo-humeral rhythm ; the scapula rotates first and only then does the humerus move on the scapula

Treatment of ruptures of the rotator cuff—Conservative treatment is often successful when tears are small and recent If the patient had no disability until an injury was sustained and the clinical features suggest incomplete rather than massive rupture treatment by immobilisation alone should be tried ; but if there have been grumbling symptoms of tendinitis for several months or years and the physical signs indicate a massive tear it is a waste of time to use a frame or plaster spica—it will be found that the smooth rounded capsular margin is pulled far away from the eburnated bone and spontaneous repair is obviously impossible

Conservative treatment—The torn fibres are brought into apposition by abduction, forward flexion and external rotation of the shoulder and this position should be maintained unremittingly for not less than eight weeks the limb must never be lowered even momentarily until the power of active abduction is regained Moreover it should be understood that in approximating the torn surfaces external rotation is just as important as abduction If a frame is used instead of a plaster spica special care is needed A platform splint supporting the limb in neutral rotation is quite useless Many failures have also arisen from the careless use of frames applied loosely with only two or three bandages so that within a few days the splint was sliding down the trunk At least ten or a dozen wide bandages are needed and they should be hitched under every available screw nut and bar and be passed over both shoulders It is still better to use a plaster spica (Fig 803)

Operative treatment[1 *]—An incision two or three inches long is centred on the top of the acromion which is exposed subperiosteally and excised The central part of the deltoid is then retracted laterally If more exposure of the front of the capsule is needed the anterior fibres of deltoid may be split for two or three inches Very small tears lie transversely just above the tuberosity but more massive tears are tri radiate in shape the supraspinatus and infraspinatus being retracted not only upwards but also backwards (Fig 722) The apex of the triangle lies near the biceps tendon one side is the bared tuberosity ; the other is a split in the capsule roughly in line with the biceps tendon and the base is the retracted part of the cuff In the course of operative repair the centre of the base must be stitched to

[1] Schaer H *Ergebn. Chir Orthop.*, 1936, 29, 211.
Codman, E. A., and Akerson, I.B *Ann. Surg* 1931, 93, 348.
Fowler, E. B. *J Amer med Ass.*, 1933 101 2106.
Davis, T W, and Sullivan, J E. *Ann. Surg* , 1937 106, 1059.
Mayer L. *J Bone Joint Surg* , 1937 19 640.
Oatland, T A., and Shepherd, W F *Ann. Surg* 1938 107 116.

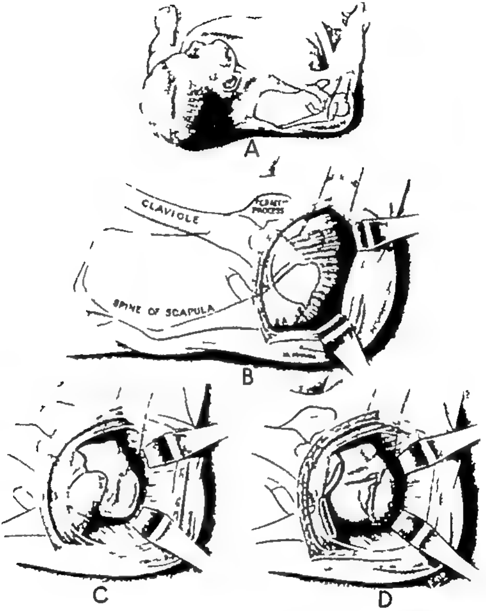


FIG 722

Operative repair of supraspinatus tendon rupture

The surgeon should stand in the anæsthetist's position looking down on the shoulder (A). A three-inch incision is made above the acromio-clavicular joint (B). The deltoid origin is reflected and the acromion process excised up to the joint (C). The tear in the capsule is exposed (D).

the apex The retracted fibres must be pulled as much forwards as outwards[1] and approximation is accurate only when the limb is externally rotated as well as abducted After freshening the tuberosity and the retracted margin of capsule fixation should be secured by mattress sutures passed through drill holes in the bone (Fig 723) The limb should be supported in a plaster spica in abduction forward flexion and external rotation for at least eight weeks.

[1] Withers, R. J W "The Painful Shoulder" J Bone Joint Surg., 1949 31-B, 414

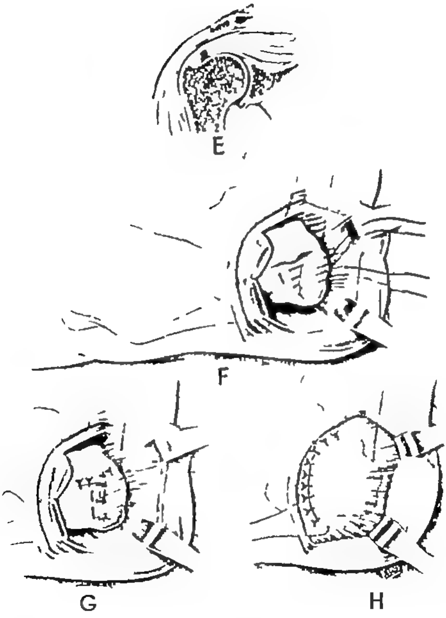


FIG 23

Operative repair of supraspinatus tendon rupture—*continued*

Although the tendon of insertion of supraspinatus is retracted upwards (E) it is also retracted backwards thus creating a tri radiate tear needing external rotation as well as abduction for approximation (F). Mattress sutures are inserted (G) and the deltoid is stitched back (H)

suggested tenodesis of the subclavius [1] It should be understood however that an unreduced sterno clavicular dislocation may not cause any disability The bone often becomes stable in its displaced position and there is no

FIG 734

FIG. 735

FIG 736

Dislocation of the right sterno-clavicular joint Failure of reduction of the dislocation does not limit shoulder movement and in this case accounts for no disability

limitation of movement (Figs 735-736) If, in recent or old cases it is decided that operative stabilisation is needed it is better to use local tissues for reconstruction—the fibrocartilage of the joint or the subclavius tendon—rather than free transplants of fascia lata

[1] Burrows, H. Jackson. "Tenodesis of Subclavius in the Treatment of Recurrent Dislocation of the Sterno-clavicular Joint. J Bone Joint S rg., 1951 33-B, 240. (The tendon is left attached at its origin from the costochondral junction but separated from the muscle the free end then being passed through a drill hole in the inner end of the clavicle thus replacing the torn rhomboid ligament)

RUPTURE OF THE BICEPS TENDON

The degenerative changes that have been described occur particularly in the part of the capsule that lies immediately to the outer side of the bicipital groove Rupture of the capsule and supraspinatus tendon may actually involve the horizontal fibres bridging the groove and the biceps tendon is then laid bare Proximal to this level the tendon is entirely intra articular and is closely apposed to the articular surface of the head of the humerus It is clear therefore that the long head of the biceps may suffer degenerative change in association with capsular degeneration and periarthritis or in association with true osteo arthritis of the shoulder joint The tendon undergoes attrition and it may rupture either spontaneously or from trivial muscular effort These predisposing factors explain the frequency of rupture of the long proximal tendon of the biceps an injury that is far more common than avulsion of the short head of the biceps from the coracoid process or disinsertion of the distal tendon from the bicipital tuberosity Although the distal tendon is exposed to similar muscle strains it is not subject to pathological degenerative changes and less than forty cases of rupture or avulsion of the tendon from the radius have been recorded [1-3] (see page 63)

Fig 724
Spontaneous rupture of the long tendon of biceps from periarthritis of shoulder

Clinical features [4-5]—The warning symptoms of pain and slight stiffness of the shoulder have usually been present for many months or even years At the moment of injury there is a sharp snap of pain and thereafter swelling and sometimes ecchymosis below the deltoid muscle As the swelling subsides characteristic hollowing in front of the upper arm becomes more conspicuous When the patient supinates the forearm or flexes the elbow against resistance the belly of the muscle retracts into the lower third of the arm and stands out as an obvious swelling which is accentuated by the hollowing above (Fig 724) There is little loss of power because the short head of biceps the brachialis anticus and the flexor muscles of the forearm are still contracting normally

Treatment—The disability caused by rupture of the biceps tendon is often unimportant and operative repair is by no means essential Nevertheless there is some loss of power and when it is an industrial injury the patient may be unwilling to return to work while there is such obvious abnormality During early weeks after the injury it is a simple procedure to stitch the distal end of the ruptured tendon to the lower part of the bicipital groove and in this way to restore normal function as well as normal appearance of the limb

Platt H "Rupture of Biceps Tendon." *Brit. med J* 1931 1, 611
Sonnenschein, H D "Rupture of Biceps Tendon." *J Bone Joint Surg.*, 1932, 14 416.
Rogers, S I Avulsion of Biceps Brachii. *J Bone Joint Surg* 1939 21 197
Gilcreest, E. L. "Rupture of Tendons (review of literature) *J Amer med Ass* 1925, 84, 1819.
Royle Jones A "Treatment of Ruptured Muscles and Tendons. *Lancet* 1925 2, 1157

DISLOCATION OF THE ACROMIO-CLAVICULAR JOINT

When the ligaments of the acromio-clavicular joint are torn, the weight of the limb pulls the scapula downwards and the acromion process lies at a *slightly lower level than the clavicle* If the degree of injury is still greater there may be rupture not only of the acromio-clavicular ligaments but also of the coraco-clavicular ligaments and thus there are two degrees of joint displacement—acromio-clavicular subluxation and acromio-clavicular dis location

Fig 737 Fig 738

Subluxation and dislocation of the acromio-clavicular joint. Complete dislocation of the joint is accompanied by rupture of the conoid and trapezoid ligaments.

Acromio-clavicular subluxation—If injury is confined to the acromio-clavicular ligaments so that the conoid and trapezoid ligaments between the coracoid process and the clavicle are intact, downward displacement of the scapula is limited and there is no more than subluxation of the joint (Fig 737) The clavicle is unduly prominent *and the examining finger passes from the upper surface of the clavicle* to the upper surface of the acromion over a palpable step In some cases the displacement is so slight that it is obscured by swelling but there is tenderness exactly over the joint and a radiograph will confirm that the articular surfaces of the clavicle and acromion are incongruous although the bones are not completely disengaged the clavicle is a little higher than the acromion.

Acromio-clavicular dislocation—If there is rupture not only of the acromio-clavicular ligaments but also of the coraco-clavicular ligaments the scapula falls away from the clavicle (Fig 738) the acromion lies below and in front of the outer end of the clavicle which can be felt in the suprascapular region just under the margin of the trapezius This is the type of acromio-clavicular injury in which ossification may be observed between the coracoid and clavicle (Fig 739) The bone is in the sub periosteal hæmatoma produced by avulsion of the conoid and trapezoid ligaments In rare cases there may be ■ fracture of the coracoid process at the point of attachment of the ligaments

Fig. 739

Dislocation of acromio-clavicular joint with avulsion of conoid and trapezoid ligaments from the clavicle and ossification of the subperiosteal hæmatoma.

Treatment—Displacement of the acromio clavicular joint is easily reduced by elevating the whole arm and shoulder girdle so that the scapula

PERIARTHRITIS OF THE SHOULDER

The condition described as periarthritis or chronic obliterative bursitis represents a more diffuse form of traumatic degeneration and inflammation of the capsule and periarticular tissues of the shoulder The symptoms may arise spontaneously, or after a trivial twist or strain Most patients are over forty years of age and many are women The pain is diffuse and tenderness is not confined to the tuberosity of the humerus Movements of the shoulder are guarded by muscle spasm but there is no complete limitation of gleno humeral movement, such as is characteristic of true arthritis Abduction and external rotation movements are limited internal rotation and forward and backward flexion are relatively free Limitation of movement by the guarding of muscles passes rapidly to limitation by adhesion formation Even a few adhesions between the surfaces of the subdeltoid bursa interfere with the gliding mechanism and such adhesions have been demonstrated at operation [1,2] In more severe cases generalised adhesion of the whole of the pericapsular tissues leads to the frozen shoulder

Treatment—In the early acute stage the worst treatment is manipulation under anaesthesia or frequent passive and forcible stretching by a masseuse Forcible treatment tears the tissues which are already inflamed and increase sero-fibrinous exudation If the range is actually measured and recorded it is found always to have been reduced by such measures On the other hand the patient must be urged to practise active exercises Massage physiotherapy and hydrotherapy may help the patient to persever despite discomfort but the one treatment of paramount importance i active exercise performed for a few minutes hourly throughout the day

STIFFNESS OF THE SHOULDER FROM ADHESION FORMATION

He must cure himself—that is the essential doctrine of physiotherapy

—F J Cotton [3]

Adhesions may develop spontaneously in cases of *periarthritis* and they may also complicate a fracture or dislocation of the shoulder or arise insidiously when a fracture of the elbow forearm or wrist is treated with the limb in a sling The shoulder may have seemed normal before injury but the predisposing factors were already present and subsequent immobility of the joint encouraged adhesion formation Every upper limb supported in a sling is immobilised with the shoulder in full internal rotation and it i the loss of external rotation movement that is significant Until externa rotation movement is restored abduction movement cannot be regained Abduction is accompanied by rotation of the shaft of the humerus [4] and i the humerus is deliberately held in full internal rotation even the norma shoulder cannot be abducted beyond a right angle The range of rotatio should be tested with the elbow to the side and the forearm and hand pointin forwards It should be possible to rotate the limb outwards through [illegible] degrees so that the forearm and hand point sideways If this movement i completely limited it is a waste of time to practise abduction exercises an to force abduction by manipulation is a wasted effort

Codman, E. A. "The Shoulder" Boston Thos. Todd Co., 1934.
Haggart, G. E., and Allen, H. A. *Surg Clin. N Amer.*, 1935, 15, 1537
Cotton, F J., and Peterson, T H. "Physiotherapy in Fracture Treatment." *J Bone Joint Surg* 1934 16, 65
McGregor L. "Rotation at the Shoulder" *Brit. J Surg.*, 1937 24 425.

and therefore the acromion are both pushed up to the clavicular level but redisplacement is just as easy from the unsupported weight of the limb For this reason the results of conservative treatment are sometimes imperfect but this is because the technique has not been applied with sufficient care With proper attention to detail there is little difficulty in securing excellent cosmetic and functional results by a method of strapping based on the original bandage technique of Robert Jones[1]

Immobilisation by strapping—The limb should be elevated by strapping which encircles the clavicle above and the elbow below A small pad of wool is placed in the axilla and the wrist is suspended from the neck by a collar and cuff sling with the elbow at the right angle A pad of adhesive

FIG 740

FIG 741

Method of strapping an acromio-clavicular dislocation. The humerus and scapula are elevated and the clavicle pulled down while the strapping is tightly applied over pads of adhesive felt.

felt is placed below the elbow to protect the ulnar nerve and the bony prominence of the olecranon with a second pad over the outer end of the clavicle The two pads are then pulled together with strips of brown holland strapping four or five feet long applied as tightly as possible (Figs 740 741) While the strapping is being fixed the humerus is pushed upwards to elevate the scapula and acromion and the clavicle is pulled downwards Even holland strapping tends to stretch by the weight of the limb and five or six layers should therefore be used moreover the fixation should be tightened every second or third day by applying additional strips over the strapping already in position The fixation should be continued for at least three weeks in subluxations of the joint and for at least five weeks when the joint is completely dislocated

[1] Jones, Robert. "Injuries to Joints." *Oxford Med Pub.*, 19 4 57

FIG 725

FIG 727

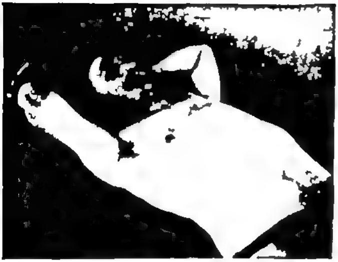


FIG 726

FIG 728

FIG 729

FIG 730

FIG 731

Shoulder exercises for periarticular adhesion formation

External rotation movement must be regained first: to perform these exercises the patient lies on a couch (Figs. 725-726) and then stands back to a wall (Figs. 727, 728). Abduction exercises are practised while standing (Figs. 729, 730). Swinging exercises are performed in all directions gently and not violently (Fig. 731). The exercises must be repeated hourly throughout the day.

It is a common mistake to apply strapping over the top of the humerus instead of over the clavicle and supraclavicular triangle (Figs 742 743) In these circumstances the surgeon is attempting the impossible task of compressing the humerus in its long axis, he is doing nothing at all to the acromio-clavicular joint The strapping must cross the supraclavicular triangle as close as possible to the base of the neck

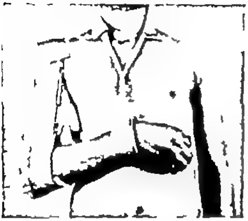


FIG 742
Incorrect method of strapping an acromio-clavicular dislocation.

FIG 743
Correct method of strapping an acromio-clavicular dislocation.

Operative treatment of recent acromio-clavicular dislocations—Various operations have been described by which to avoid the difficulties and discomforts of immobilisation by strapping and to secure more complete fixation of the joint

Acromio-clavicular suture—Suture of the acromion to the clavicle by kangaroo tendon or wire is almost certain to fail because the whole weight of the limb is concentrated as a shearing force on an unstable joint The suture breaks the wire cuts through and the bones redislocate

Acromio-clavicular transfixion by wires and pins—Murray [1] transfixed the joint by Kirschner wires which were allowed to protrude through the skin and were removed after the torn ligaments had healed This technique involves the risk of infection spreading along the pin tracks Phemister [2] advocated transfixion by two short pins driven through the acromion into the clavicle with the ends buried under the skin but left projecting far enough to facilitate their removal after two months There is danger of the wires breaking and two cases have been reported of migration of wire into the lung [3]

Coraco-clavicular fixation by screw—A method described by Bosworth [4] and devised independently at about the same time by Vere-Hodge in England made no direct attack on the joint itself but secured fixation by screwing the clavicle to the coracoid (Fig 744) This technique is more reliable than transfixion of the joint with pins but it cannot be relied upon without the external support of properly applied strapping An unprotected screw loosens in the bone even if a washer of cortical bone or ivory is placed under

[1] Murray, Gordon L. "Fixation of Dislocation of Acromio-clavicular Joint." *Canad. med Ass J.*, 1940 43, 270.
[2] Phemister, D B. "Treatment Acromio-clavicular Dislocation by Open Reduction and Threaded Wire Fixation." *J Bone Joint Surg.*, 1942, 24, 166.
[3] Mazet, R., Jun. "Migration of Kirschner Wire from Shoulder into Lung. *J Bone Joint Surg.*, 1943 25, 477
[4] Bosworth, B M. "Acromio-clavicular Separation." *Surg Gynec Obstet.*, 1941 73, 866.

Treatment by active exercises—The essential object of treatment is to regain the range of external rotation movement This is not to be achieved by massage stretching or manipulation Successful treatment may be summed up in two words—*active exercise* Discomfort and pain may be temporarily aggravated but the patient must persevere Exercises should continue for at least five minutes every hour of the day Encouragement and persuasion are often necessary but there must be no force and no passive stretching either by masseuses or well wishers or by hanging by the affected limb from overhead bars The exercises must be done smoothly and without sudden jerking movements

Exercises in recumbency—(1) The patient lies on his back with the elbows to the side and the hands pointing to the ceiling and gradually turns the forearms further and further out until the hands reach the bed (Fig 725) (2) Both shoulders are abducted to the right angle and the patient endeavours to reach the bedposts behind his head with each hand (3) The fingers of both hands are clasped behind the neck with the elbows forward and the elbows are then pressed back into the position of abduction until they touch the bed (Fig 726) (4) When external rotation movement is recovering abduction exercises are practised by reaching over the top of the head with the hand of the affected side until finally the fingers touch the ear of the opposite side (Fig 729)

Standing exercises—The same movements are performed while the patient stands with his back to a wall The elbows touch the wall and both forearms are turned out until the hands also reach it (Fig 727) The fingers are clasped behind the neck and both elbows are pressed back until they touch the wall (Fig 728) The patient stands sideways to the wall and reaches higher and higher with the finger tips marking the level he reaches and always attempting to improve on previous efforts (Fig 730) Later full internal rotation movements should be practised by placing the hand behind the back and stretching to higher levels until the midscapular region is reached by the finger tips

Stooping exercises—While the patient stoops half forwards the limb is gently swung from before backwards and from side to side the excursion of movement gradually increasing (Fig 731) Circumduction is also practised —but all of these swinging exercises must be gentle and not violent

Manipulation under anaesthesia—Manipulation should not be employed during the early stages while inflammation is acute and the adhesions are vascular *Many shoulders stiff after dislocation and minor injury have been made permanently stiff by injudicious manipulation performed too soon repeated too often and followed by passive and forcible stretching* Manipulation is advisable only when measurements show that movement is no longer increasing by the patient's own exercise If a manipulation is necessary it must be done as gently as possible and not more than one group of adhesions should be broken at a time If too much is done the reaction is so severe that the movement cannot be retained and the joint may become stiffer This cannot be avoided by bandaging the arm to the head of the bed, or by supporting it in hyperabduction by a plaster cast [1] It is no easier to regain adduction movement from the position of abduction than it is to regain abduction movement from the position of adduction

[1] Scheer H. Ergebn Chir Orthop., 1936 29, 11.

FORWARD DISLOCATION OF THE SHOULDER JOINT

It used to be taught that traumatic dislocation of the shoulder was the result of violent abduction of the arm which levered the neck of the humerus against the acromion and drove the head down through a tear in the inferior part of the capsule and that recurrent dislocation was quite a different injury in which the fibro cartilaginous labrum and capsule were torn from the front of the glenoid fossa by a direct blow from behind which drove the head of the humerus forwards It was said that whereas tears of the capsule healed easily and quickly avulsions of fibro cartilage from bone healed only with difficulty and uncertainty Thus arose the views that ordinary dislocations needed no immobilisation that recurrent dislocations were destined to be recurrent from the beginning and that short of operation a surgeon could do nothing to prevent recurrence even at the time of original injury I never believed this None of several hundred primary dislocations that I had treated with strict immobilisation of the shoulder for at least three weeks had recurred whereas every patient seen with recurrent dislocation had been treated elsewhere by early mobilisation after the first dislocation or at most by a form of support that did not at all times hold the limb rigidly in full internal rotation

We now believe that the former distinction was wrong and that there is in fact no difference in the mechanism of injury or pathological anatomy between non recurrent and recurrent dislocations [1] Some few dislocations arise from forcible abduction which drives the head of the humerus down below the glenoid (*luxatio erecta* where the limb is locked in full abduction) but most dislocations non recurrent as well as recurrent occur from violence that drives the head forwards The commonest injury is a fall on the outstretched hand and even if the patient falls with the limb partly in front of the trunk the force is still resolved into a forward drive of the humerus on the glenoid because the joint is in a plane directed obliquely forwards [2] Sometimes the joint is dislocated by a fall backwards either on the hand or on the point of the elbow behind the trunk when the forward drive is more obvious It may be dislocated by forcible external rotation movement which twists the head of the humerus forwards or by forcible extension of the partly abducted arm as in a hand-off at football which thrusts it forwards Always the head is driven forwards and nearly always the capsule is avulsed from its glenoid attachment or sometimes from its humeral attachment if it is torn from the glenoid the labrum may be displaced with the capsule or remain attached to the bone if the capsule is torn from the humerus the tendon of subscapularis is torn with it But no matter whether there is a tear in the capsule itself or as more usually an avulsion of capsule from the scapula it will heal only if it is given an opportunity to heal by complete protection from external rotation movement during the first three weeks If it is not so protected the dislocation will recur wherever the site of capsular injury may be [3]

[1] The difficulty in confirming this view is that primary dislocations of the shoulder are seldom examined at operation or autopsy—but the few that have been so examined confirm it and all the evidence supports my belief that dislocations of the shoulder are just like dislocations of every other joint.

[2] Adams, J C "Review 180 Cases Recurrent Dislocation of the Shoulder" *J Bone Joint Surg.*, 1948 30-B 6

[3] Eyre Brook has described recurrent dislocation where the capsule was avulsed from the humerus and the tendon of subscapularis was torn. *J Bone Joint Surg* 194 30-B 39

If the surgeon prohibits passive stretching and the patient co-operates in treatment, the prognosis in these cases is good and complete recovery may be expected with confidence I have been astonished and amazed in recent surgical conferences to learn how general is the gloom and despair of surgeons on the problem of periarthritis and periarticular adhesions of the shoulder Such pessimism is unjustified. The surgeon must of course work hard in stimulating and persuading the patient—and at the same time he must restrain from violence and ill-advised operations such as the stupid proposal of excising the biceps tendon or fusing the tendon in the bicipital groove for stiffness of the shoulder [1-3] If violence is avoided and encouragement assured recovery is almost certain

FIG 732
Application of figure-of-eight bandage for fracture of clavicle.

FRACTURE OF THE CLAVICLE

Healthy men have been incapacitated for many years by simple fractures of the clavicle The injury need not cause more than a few weeks of incapacity but if Sayre's strapping is used and the fingers and hand are strapped flat against the chest wall the finger joints become so stiff that they may never recover, and when the fingers are stiff there is so little incentive to use the limb that even stiffness of the shoulder becomes a problem. Whatever method of treatment is used for fractures of the clavicle the finger joints should be exercised actively from the beginning

The fracture usually occurs in the middle third of the bone from a fall on the outstretched hand or on the side of the shoulder There is often overriding of the fragments the inner being displaced upwards by the pull of the sternomastoid and the outer displaced downwards and inwards by the weight of the limb The outer fragment must be replaced in alignment with the inner by pulling the whole shoulder girdle upwards and backwards There is difficulty in maintaining this position—a difficulty demonstrated by the fact that over one hundred methods of treatment have been described. It is doubtful whether any of them can be relied upon always to maintain perfect anatomical reposition and sound union without bony thickening Fortunately even when treated by the simplest technique the fracture almost invariably unites in about three weeks Moreover thickening from imperfect reduction usually disappears within a few months [4]

Treatment—*The figure-of-eight bandage* method is simple and if carefully used gives excellent results The patient sits on the edge of a stool and the

Lippmann, R. K. "Frozen Shoulder Bicipital Tenosynovitis." *Arch Surg.*, 1943 47 283.
Lippmann, R. K. "Bicipital Tenosynovitis. *N Y St. J Med.*, 1944, 44, 2235.
Simmonds, F A. "Shoulder Pain Frozen Shoulder" *J Bone Joint Surg.*, 1949, 31-B, 426.
Greenwood, H H "Treatment Fractures of Clavicle." *Brit. med. J.*, 1925 1 1021.

There is no longer any mystery about it. Dislocations of the shoulder joint are just the same as dislocations of other joints and recurrent dislocations are the same—they arise from faulty treatment of the first injury[1]. It is to be noted again in common with injuries of other joints, that bone injury complicating a first dislocation may predispose to recurrence. As the head of the humerus is driven forwards there may be a fracture of the anterior margin of the glenoid or a compression injury of the postero lateral sector of the head of the humerus which engages with the anterior margin of the glenoid. These complicating fractures make it all the more important to immobilise the first dislocation in a position of full internal rotation.

Fig. 766

Fig. 767

Subcoracoid dislocation of the shoulder. Note the flattening of the contour of the shoulder and the projection of the elbow from the side (Fig. 766). The line of the arm indicates a subcoracoid position of the head of the humerus (compare with the radiograph (Fig. 767)). The diagnosis should be obvious at a glance.

Clinical signs of subcoracoid dislocation—Since the head of the humerus does not occupy its normal position the shoulder loses its round outline and the acromion is unduly prominent owing to the hollow beneath it (Figs. 766-767). All movements are limited and painful and there is difficulty in putting the elbow to the side because the upper end of the humerus is locked in its inwardly displaced position.

Unusual forward dislocations—When the joint is dislocated forwards the head of the humerus usually lies in front of the glenoid below the coracoid process. In one unusual case it was driven between the clavicle and first rib[2]. A still more remarkable displacement was that described by West[3] in which the head of the humerus was driven into the chest between the

[1] The exception is the patient who has a congenital anomaly of the joint with insecure attachment of the glenoid labrum so that even before an injury has been sustained there is predisposition to dislocation and, of course, to recurrent dislocation. Gallie, W. E., *J. Bone Joint Surg.*, 194[illegible], 30-B, [illegible].
[2] Bankart, A. S. B., "Dislocations—Shoulder Joint." Robert Jones Birthday Volume, *Oxford Med. Pub.*, 1928, 307.
[3] West, E. F., "Intrathoracic Dislocation of the Humerus," *J. Bone Joint Surg.*, 1949, 31-B, 61.

DISLOCATION OF THE BASE OF THE FIFTH METACARPAL

Although fracture-dislocation of the base of the thumb metacarpal occurs so commonly, dislocation of the base of the fifth metacarpal is unusual Cases have been recorded by McWhorter Buzby, Roberts and Holland[1 3] Two types of dislocation may be differentiated In the first the base of the metacarpal is displaced medially to the ulnar side Reduction is seldom difficult but continued traction or skeletal transfixion may be needed to prevent redisplacement In the second type which is more frequent, the metacarpal is displaced laterally across the palm in front of the base of the fourth metacarpal bone Only in the case reported by Murless[1] was

Fig 1026

Two months old unreduced dislocation of the base of the fifth metacarpal

Fig 1027

Same case, after operation reduction and arthrodesis of the carpo-metacarpal joint.

manipulative reduction successful In other reported cases operative reduction was needed The case shown in Figure 1026 was sustained by a policeman from a fall on the ulnar side of the wrist Seven weeks elapsed before the patient was first seen The base of the fifth metacarpal lay in the palm in front of the third and fourth metacarpals An incision was made over the ulnar border of the hand and the displaced metacarpal was pulled back into position by a hook The operation presented no difficulty but there was such erosion of the articular surfaces that it was decided to arthrodese the joint The hand was immobilised in plaster for six weeks and full function was regained without disability (Fig 1027) In the future when these cases are recognised and treated more promptly it seems likely that manipulative reduction will usually succeed

McWhorter Dislocation of the Fifth Metacarpal." *Surg Cl n., Chicago*, 1918 2, 793.
Buzby "Palmar Carpo-metacarpal Dislocation *Ann. Surg* 1934, 100 555
Roberts, N., & Holland, Thurstan Dislocation of the Base of the Fifth Metacarpal." *Brit. J Surg.*, 1936 23, 567
Murless, B. C Fracture Dislocation of the Base of the Fifth Metacarpal Bone." *Brit J Surg.*, 1944, 31 402.

third and fourth ribs It was pulled out with a pop like that of a cork from a bottle and the patient made a complete recovery One other such case of intrathoracic dislocation of the head of the humerus was described in 1803 [1]

Subglenoid dislocation—The rare subglenoid dislocation has been mentioned With the head of the humerus lying below the inferior margin of the glenoid the limb is locked in a position of full abduction by the side of the head It is described as *luxatio erecta*

Nerve injuries—One in seven dislocations of the shoulder is complicated by paralysis from primary traction injury of the branches of the brachial plexus This high incidence may not be recognised unless every patient is specially examined for nerve lesions [2] The muscle most commonly involved is the deltoid which may be paralysed by injury to the circumflex nerve the posterior cord of the plexus or the outer trunk of the plexus The frequency of circumflex nerve injury is explained by the short fixed course of the nerve from the back of the axilla round the outer side of the humerus to the front a course that makes it difficult to escape traction injury when the humerus is displaced forward Deltoid paralysis may be recognised in the earliest stages even without moving the limb by palpating the muscle belly with one hand and instructing the patient to attempt abduction movement against the resistance of the examiner's other hand over the patient's elbow

The susceptibility of the circumflex nerve to injury in dislocation of the shoulder joint is illustrated by one of Lawson Dick's cases in which a boy of seventeen playing Rugby football sustained a dislocation which was reduced within a few seconds on the touch line he went on playing and later scored a try Nevertheless there was permanent paralysis of the anterior two-thirds of the deltoid muscle Despite permanent paralysis of the muscle caused by dislocation of the shoulder joint reduced so promptly, the boy regained such power in the supraspinatus that he rowed for his college at Cambridge

Vascular injuries—Occasionally the displaced head of the humerus presses on the axillary vessels Until the dislocation is reduced the hand may be blue and cold Rupture of the axillary artery [3] and traumatic aneurism sometimes occur especially after attempted manipulative reduction of old dislocations by forcible manipulation One patient had sustained many recurrent dislocations of the shoulder which he often reduced himself they gave rise to little disability until finally when he was an old man with atheromatous vessels one recurrence caused rupture of the axillary artery from which he died

Treatment of subcoracoid dislocation [4-6]—*Kocher's manipulation*—The head of the humerus is held in its inwardly displaced and inwardly rotated position by retraction and shortening of the subscapularis To reduce the dislocation this muscle should be gently but firmly stretched to its normal length by Kocher's manipulation The patient lies on a couch and the surgeon stands at his side For a dislocation of the right shoulder the surgeon

Anger B "Traité iconographique des maladies chirurgicales." Paris G Baillière 1865, page 79
Murray C R. "Dislocation of the Shoulder" *J Amer med Ass.* 1931, 96, 237
Kirker J R Dislocation of Shoulder with Rupture of Axillary Vessels." *J Bone Joint Surg.*, 10.., 34-B, 72.
Kocher, E. T *Berl. kl n. Wschr* 1870 7, 101
Nash J "Kocher' Method of reducing Dislocation of Shoulder" *J Bone Joint Surg.*, 1934 16, 535.
Mileh, H Treatment of Dislocation of Shoulder" *Surgery St Louis* 1939 3, 732.

DISLOCATION OF OTHER CARPO-METACARPAL JOINTS

Free mobility of the thumb is an essential part of the function of the hand and this accounts for the relative frequency of fracture-dislocations of its carpo metacarpal joint—and for the importance of correcting such displacements The other carpo-metacarpal joints have a much more restricted range of movement and they are more stable It is true that the carpo metacarpal joint of the fifth finger is sometimes dislocated as discussed on the last page but displacements of the carpo-metacarpal joints of the index middle and ring fingers are unusual Moreover there is relatively little functional disability even if such displacements are imperfectly corrected.

When this row of joints between the distal carpal bones and the bases of the metacarpals is injured the metacarpals are usually displaced backwards,

Fig 1028

Backward dislocation of the second, third and fourth metacarpals. The displacement is concealed in the antero-posterior view but obvious in the lateral view It was easily reduced by manipulation.

but occasionally they are displaced forwards Figure 1028 shows the most frequent type of displacement In this case the second, third and fourth metacarpals were dislocated backwards from the distal row of the carpus Reduction was secured without difficulty by an assistant applying traction to the fingers while the surgeon pressed with the base of his thenar eminence over the back of the metacarpals against the counter pressure of his other hand over the front of the carpus A closely moulded dorsal plaster cast was applied for three weeks active exercises of the fingers being practised from the beginning

Less commonly there is forward displacement of the metacarpals into the palm of the hand Figure 1029 shows dislocation of the whole row of carpo-metacarpal joints all four metacarpals being displaced forwards It was reduced by closed manipulation with traction and direct pressure in the base of the palm by Miss Pearson at Raigmore Hospital Scotland—and we must congratulate her on successful treatment of a difficult injury

takes the elbow in his right hand and the wrist in his left Firm traction is applied to the humerus by pulling with the right hand While traction is maintained the humerus is very gently and smoothly laterally rotated by moving the forearm out until the normal limit of 80 degrees of external

Fig 768

Fig 769

Fig 770

Fig 771

Kocher s method of reducing dislocation of the shoulder Traction is applied The limb is gently and slowly rotated outwards. The elbow is brought forward in front of the trunk and the shoulder is then rotated inwards.

rotation is reached The limb being kept in external rotation the elbow is brought forward in front of the chest Finally the limb is rotated inwards and the hand is brought over to the opposite shoulder (Figs 708-771) The manipulation is performed so gently and smoothly that the head of the humerus glides into position and often the surgeon does not know the stage at which the dislocation is reduced There is no need to elicit any click

Fracture of the outer end of the clavicle—In fractures of the outer end of the clavicle the small outer fragment remains attached to the acromion process and scapula The injury is comparable to acromio-clavicular dislocation If the coraco clavicular ligaments are ruptured the outer fragment is displaced forwards and downwards and strapping encircling the elbow and clavicle is necessary for about three weeks

Un united fracture of the clavicle—Non union although rare [1,2] is occasionally seen after primary operative reductions especially when fragments of bone have been removed The sclerosed bone should be freshened the fragments placed in apposition and a tibial bone graft onlayed by the usual technique with vitallium or stainless steel screws In order to prevent ridges and spurs of bone projecting subcutaneously the graft should be applied deeply on the inferior surface of the bone and the heads of the screws should be countersunk An alternative to onlay grafting with screws is intramedullary fixation with a stainless steel pin or heavy Kirschner wire and transplants of iliac cancellous bone packed firmly between the freshened surfaces of the fragments Whichever technique is used the complete support of a shoulder spica for two or three months is essential

Vascular injury complicating fracture of the clavicle—Few remember that Sir Robert Peel who created the police force of Great Britain in the first half of the nineteenth century (so that we still refer affectionately to our police as Bobbies) died of a fractured clavicle He was attended by Sir Benjamin Brodie who wrote The hæmorrhage itself was the consequence of the subclavian vein having been lacerated by the splinters of the fractured bone [3] Other cases of injury to the subclavian artery or vein have been recorded,[4] and one example of this rare complication is illustrated on page 103

DISLOCATION OF THE STERNO-CLAVICULAR JOINT

The inner end of the clavicle may be dislocated forwards and downwards (Fig 734) sometimes it is displaced upwards and in rare cases there is backward or retrosternal displacement with dyspnœa from pressure on the trachea [5-8] It is seldom difficult to replace the forwardly dislocated sternal end of the clavicle by pulling the shoulder girdle upwards and outwards exactly as for fractures of the clavicle but it is difficult to prevent redisplacement A reasonably good position may be maintained by the ordinary figure-of-eight bandage with large axillary pads over which the weight of the limbs maintains distraction but if reduction is unstable operative fixation should be considered It may be possible to suture the torn tissues and reinforce them with strips of adjacent muscle and fascia I have had success by stitching the meniscus of the joint across the front of the bone Strips of fascia lata may be used to anchor the clavicle to the first or second ribs or to the sternum [1,10] and Jackson Burrows has

Berkheiser E. J "Old Un-united Clavicular Fractures in the Adult." *Surg Gynec Obstet.*, 1937, 64, 1064
Ghormley, R. K., and others. "Un-united Fractures of the Clavicle." *Amer J Surg* 1941 N.S. 51 343.
Holmes, T "Sir Benjamin Collins Brodie. London T. Fisher Unwin 1898.
Dickson, J W "Death following Fractured Clavicle" *Lancet* 1952, 2, 666.
Nissen, H. "Retrosternal Dislocation of Clavicle" *Dtsch. Z Chir* 1931 231 405.
Kennedy J C "Retrosternal Dislocation of the Clavicle. *J Bone Joint Surg.*, 1949 31-B, 74.
Richard, M "Treatment of Sterno-clavicular Dislocation." *Zbl. Chir.*, 1930, 57, 1460.
Allen, A. W "Living Suture Grafts in Repair of Fractures and Dislocations." *Arch. Surg* 1928, 16, 1007
Lowman, C. L. "Correction of Old Sterno-clavicular Dislocation" *J Bone Joint Surg*, 1928, 10, 740.
[10] Bankart, A S. Blundell. "Recurrent Sterno-clavicular Subluxation." *Brit. J Surg.*, 1938 26, 320.

or jerk and often such a click indicates not successful reduction but movement from one dislocated position to another Most important of all the external rotation movement must be performed slowly and gently It is easy to tear the subscapularis by forcible rotation and I have seen two cases where a spiral fracture of the neck of the humerus was produced careless manipulation had converted a dislocation—one of the most simple of all shoulder injuries into a fracture dislocation—one of the most difficult of all shoulder injuries

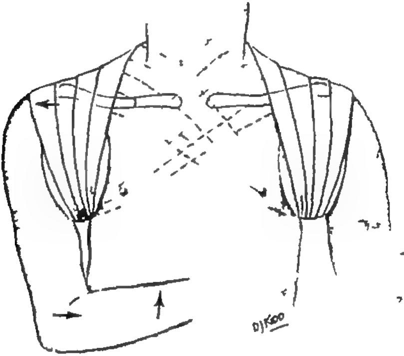
Hippocrates manipulation—If this manœuvre fails to reduce the dislocation at the first attempt the Hippocratic method of traction against the counter pressure of the unbooted foot in the axilla should be employed

FIG 772

Hippocrates method of reducing dislocations of the shoulder After two thousand years this technique is once more gaining the repute it deserves. It does not cause nerve palsy or damage to the axillary artery or vein

(Fig 772) The patient lies flat and the surgeon grasps the wrist with both hands He places his stockinged foot against the ribs close to the axilla (the right foot for a right shoulder dislocation and the left foot for a left dislocation) and with knees and elbows straight he leans back and applies firm steady traction The limb is carried slightly inwards so that the head of the humerus is levered out over the surgeon s foot and is thus guided to the glenoid fossa While traction and leverage are being maintained the limb may also be externally rotated This method has been credited with the responsibility of producing nerve lesions but if patients are examined before manipulation it will be found that the nerve lesion is already present It is difficult to believe that paralysis could be produced by pressure for half a minute against a surgeon s foot which itself is not insensible and moreover does not lie in the axilla but is placed between the chest wall and the shaft of the humerus

operator stands behind with one foot on the stool and his knee between the patient's shoulder blades (Fig 732) A large pad of wool is placed in front of each shoulder extending into the axilla Several long bandages five or six inches wide are then applied in the form of a figure-of-eight, passing in front of the shoulders and crossing between the shoulder blades The limb is supported by a triangular sling tied over the opposite shoulder The finger wrist and elbow joints should be exercised at regular intervals The bandage and sling are discarded after three weeks when there will be clinical evidence of union there is no need to wait for radiographic evidence of union—which is much more delayed



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reduction The only certain indication
in the very rare complication of com
by displaced bone

Reduction of luxatio erecta—Luxatio erecta is easily reduced by applying traction to the limb with roller towels over the chest and supraclavicular region for counter traction then bringing the arm down to the side

Testing for rupture of the supraspinatus tendon—Before the limb is immobilised with strapping and bandage the patient should be instructed to abduct the arm in order to test for rupture of the supraspinatus tendon It is important to make this test at once because if a limb with supraspinatus rupture is immobilised by the side many weeks or months may elapse before the complication is recognised the only treatment then available is a difficult operative suture If on the other hand the complication is recognised immediately and the limb is immobilised on a frame in the abducted externally rotated position complete functional recovery is usually secured even without operation

After-treatment—*If there is no rupture of the supraspinatus cuff* adhesive strapping as well as bandage should be applied round the arm forearm and trunk so as to prevent external rotation movement of the shoulder, the limb being supported in a sling For three weeks the humerus must be kept in a position of full internal rotation The fingers hand and wrist must not be covered and these joints are exercised constantly After three weeks shoulder movements are regained by active exercise There must be no passive stretching this is the cause of permanent stiffness of the shoulder and of myositis ossificans [1] There is no danger of permanent stiffness from three weeks immobilisation of the injured shoulder provided that full movement is retained in the distal joints and passive stretching and manipulation under anæsthesia are avoided Recovery is usually complete within eight weeks

Dislocation with fracture of the great tuberosity—In nearly 30 per cent of dislocations of the shoulder there is a fracture of the great tuberosity from contusion of the bone against the margin of the glenoid fossa (Fig 773) The fracture seldom adds to the difficulties of reduction [2] and in many cases the fragment is a large one which retains periosteal attachments at its base so that it is incompletely separated from the humerus post reduction radiographs show that it is lying in a perfect position The same after treatment as for uncomplicated dislocations may therefore be pursued On the other hand if the fragment is smaller and is completely detached it will be retracted by the supraspinatus muscle (Figs 774-775) It is then essential to immobilise the shoulder in abduction external rotation and forward flexion If an abduction frame is used it is most important to bandage it securely to the trunk and shoulders in order to prevent redislocation (Fig 777) With a skilfully applied frame the abducted position is perfectly safe

Dislocation with avulsion of supraspinatus—*Avulsion of the supraspinatus* tendon is an important complication of shoulder dislocation The lesion cannot be diagnosed radiographically and may therefore be overlooked If it is not recognised immediately after reduction of the dislocation many weeks or months may elapse before the diagnosis is established When slings and bandages have been discarded and the patient is practising shoulder

[1] Malkin, S A, S Myositis Ossificans of the shoulder *Proc. Roy Soc. Med.* 1933 27 1265.
[2] But in one case of dislocation of the shoulder with fracture of the great tuberosity, arising from convulsive therapy the biceps tendon was interposed between the detached fragment and the neck of the humerus (Henderson R S *J Bone Joint* ry 105_ 34-B 40).

exercises it is found that active movement is recovering less rapidly than passive movement If the deltoid is contracting normally a smaller range of active than of passive abduction points to avulsion or rupture of the tendon If too long a period has not elapsed it may still be possible to secure functional recovery by prolonged immobilisation in a frame in the position of 90 degrees abduction 60 degrees external rotation and 40 degrees forward flexion But as a rule when the diagnosis is not made within the first few days operative suture is necessary

Late unreduced dislocation of the shoulder—Old unreduced dislocations of the shoulder joint raise many problems of treatment Every day of delay increases the difficulties and dangers of manipulative and operative reduction Many disasters have occurred—the neck of the humerus has been fractured the brachial plexus has been damaged the axillary artery has been torn and in planning the treatment of dislocations which are of

FIG. 778

Simple dislocation of shoulder

FIG 779

Dislocation with fracture of great tuberosity

FIG 780

Dislocation with avulsion of supraspinatus.

many weeks or months standing these complications must be recalled particularly since reasonably good function is often regained despite the stiffness of an unreduced dislocation

Reduction by Hippocratic traction—When only two or three weeks have elapsed the safest method by which to attempt manipulative reduction is the original technique of Hippocrates Traction is applied to the limb in the position in which it lies against the counter pressure of the surgeon s foot placed between the chest wall and humerus (Fig 772) The manœuvre is often successful Kocher s manipulation is more dangerous because in late cases the humerus may be fractured Traction in the abducted position is still more dangerous because it is liable to damage the brachial nerves and axillary artery which are stretched over the displaced head of the humerus

Traumatic axillary aneurism from traction in abduction—Fairbank tells me of the case of a man aged sixty with a five weeks old dislocation of the shoulder joint in whom two unsuccessful manipulations had already been made Reduction was attempted under full anæsthesia Kocher s method was quite useless An unsuccessful attempt was then made to push the

the capsule an operation described as long ago as 1906 by Perthes[1] but this is no more easy because the staple must be driven in a difficult postero lateral direction in the depths of a deep wound Moreover the staple may penetrate the joint surface and need later removal or it may work loose from the bone and lie free as a foreign body—it is better to use a mattress stitch

After repair of the labrum the divided capsule and subscapularis should be sutured with overlapping the medial part of subscapularis being stitched to the site of the original insertion so that both capsule and tendon are shortened by nearly one inch thus restricting the range of external rotation movement The importance of this step is of course greater when there is a large bone defect in the back of the humerus—and in the 13 per cent of recurrent dislocations in which there is no labral detachment at all bone compression being the only lesion it is the essential part of the operative repair

Putti Platt operation —In this operation no attempt is made to suture the detached labrum but even more emphasis is put on shortening and double-breasting the subscapularis and anterior capsule The approach is the same as in Bankart s operation and the subscapularis tendon is divided one inch from its insertion together with underlying capsule The front of the glenoid margin is freshened with an osteotome and without more ado the lateral stump of subscapularis and capsule is sutured to soft tissues in front of the neck of the scapula the medial stump of subscapularis is then lapped over the lateral part of the tendon and sutured to the region of the lesser tuberosity (Figs 791 794) Once again the success of the procedure depends upon limiting external rotation movement so that the humeral bone defect cannot engage with the front of the glenoid

Post-operative treatment—After both these operations the reinforced and tightened capsule must be protected from external rotation movement for about four weeks The limb should be bandaged to the trunk with adhesive straps binding the forearm to the chest so that the humerus is always in internal rotation Active exercises should then be practised and within three or four months a full range of abduction will be regained External rotation movement (as tested with the elbow by the side and the forearm pointing outwards) is permanently restricted to about 40 degrees but this causes no disability at all

Dangers of restricting lateral rotation and shortening the subscapularis too much—At the end of the operation no matter what type of anterior capsular repair is used it should be possible to bring the humerus to neutral rotation without unduly straining the line of capsular suture If the capsule and subscapularis are shortened still more fixed internal rotation contracture of the joint makes it difficult to regain abduction movement In one patient in whom I tightened the tissues too much more than eighteen months elapsed before abduction to 100 degrees was regained and this was at the cost of twice mobilising the joint under anaesthesia, which for me is a rare and unusual treatment and in another the fixed internal rotation was so great that in endeavouring to mobilise the shoulder the patient developed recurrent forward subluxation of the sterno-clavicular joint the vigour of his external

Perthes, G C, *Dtsch. Z. Chir.*, 1906 104 1
Osmond-Clarke H "Habitual Dislocation of the Shoulder" *J Bone Joint Surg* 1948 30-B, 19.

humerus backwards and outwards with the arm across the chest During this manœuvre the pulse at the wrist was temporarily obliterated but it returned A further attempt was then made to reduce the dislocation by traction in the abducted position This time the pulse disappeared and failed to return When the patient had recovered from the anæsthetic the limb was completely paralysed and the radial pulse was still absent Immediate exploration of the axillary artery was urged but it was not until some weeks later that persistence of pain finally induced the old man to consent The vessel had been torn and there was a traumatic aneurism Ligation of the artery above and below with excision of the aneurism gave rise to some improvement in the paralysis

Rupture of axillary artery from operative reduction—Equally disastrous results may occur when operative reduction of late unreduced dislocation of the shoulder joint is attempted In one case the operation was foolishly undertaken by a young resident surgical officer and a strong adhesion was divided Before hæmorrhage from the severed axillary artery had been controlled the limb was completely and permanently paralysed A similar accident occurred in the practice of one of the most experienced orthopædic surgeons in this country and it seems obvious that late operative reduction of shoulder dislocations is a procedure of considerable difficulty and danger

Conservative treatment of late dislocation—If there is no complication from pressure of the displaced head of the humerus on the axillary nerves or vessels operative reduction is seldom indicated in elderly patients If cautious manipulation by the Hippocratic method has failed the disability of a stiff shoulder should be accepted Surprisingly good function is often regained

Operative reduction of late dislocation—Operative reduction is indicated in younger patients especially when there is already pressure on the axillary nerves and vessels Bennett [1] has reported successful results Replacement is obstructed by tight contracture of the subscapularis [2] by general fixation and adhesion of periarticular tissues and sometimes by interposition of the biceps tendon [3-4] The glenoid fossa should be cleared the subscapularis and contracted capsule divided and the head of the humerus replaced If the capsule is so damaged that there is danger of redislocation Nicola s transplantation of the long head of the biceps may be advisable

BACKWARD DISLOCATION OF THE SHOULDER JOINT

The head of the humerus may be displaced backwards by a direct blow over the front of the joint (Fig 781) or by violent internal rotation movement Zadik [5] recorded the case of a young enthusiast who sparred with the light-weight champion of Great Britain and in this unequal contest he retreated until his back was against the wall bars whereupon the champion delivered a heavy blow to the front of his right shoulder,

Bennett, G E. Old Dislocations of the Shoulder J Bone Joint Surg 1930, 12, 594.
Dollinger, J Ergebn Chir Orthop 1911 2, 63.
Cubbins W Callahan J , Scuderi, C " Irreducible Shoulder Dislocations. Surg Gynec Obstet., 1934 58, 129.
Gray C H Anterior Dislocations of the Shoulder Joint. Lancet 1930 1, 926
Zadik F R. Recurrent Posterior Dislocation of the Shoulder Joint." J Bone Joint S rg., 1948 30-B, 531.

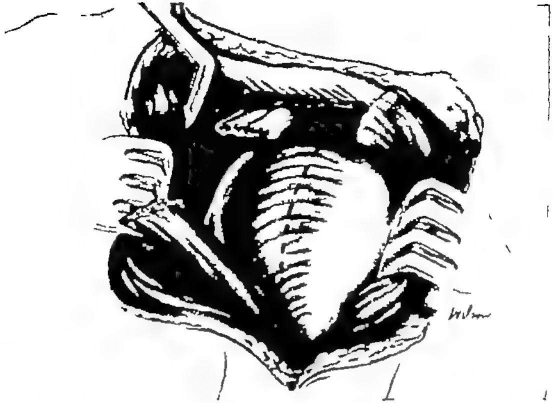

FIG. 791

The coraco-brachialis has been divided close to the coracoid process and retracted downwards. Note the line of division of subscapularis and the underlying capsule.

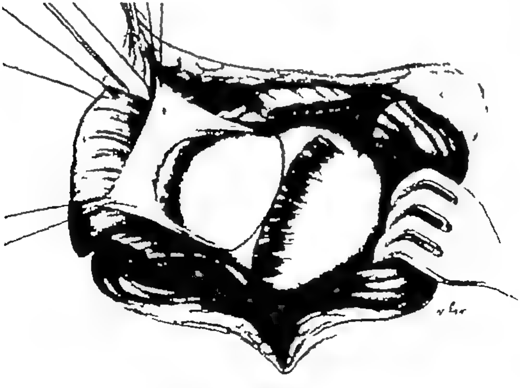

FIG. 792

The medial part of subscapularis and the capsule being retracted inwards the detachment of the glenoid labrum (Bankart's lesion) is exposed.

(Figures 791–794 are reproduced by kind permission of Mr Osmond-Clarke and the publishers, Messrs E. & S. Livingstone Ltd., from the British volume "Journal of Bone and Joint Surgery" 1949 30-B, 18.)

knocking the head of the humerus directly back from the glenoid fossa of the fixed scapula In other cases in falling on the outstretched hand the patient's trunk is rotated towards that side, so that the limb is forcibly rotated inwards and the humerus is driven backwards[1,2] The dislocation shown in Figures 782 784 was sustained from violent movement during convulsive therapy

Backward dislocation of the shoulder in which the head of the humerus lies behind the glenoid in a subspinous position is the exact counterpart of forward dislocation, the capsule and labrum being torn from the *posterior* margin of the glenoid, sometimes with a fracture of this margin and more

Fig 781

Backward dislocation of the humerus from direct violence—a blow over the front of the joint from the back of a lorry while cycling (C. K. Warrick's case *J Bone Joint Surg.*, 1948 30-B, 651). The displacement is less obvious in the antero-posterior radiograph than in the axial projection.

often with a compression fracture of the *antero-medial* sector of the head of the humerus This displacement is uncommon because nearly all *injuries* to which the shoulder is subjected including most falls on the outstretched hand and all external rotation and extension strains drive the head forwards The opposite strain of internal rotation with backward drive is obviously unusual but it does occur sometimes and the surgeon must be on guard not to overlook posterior displacement by reason of its rarity Moreover he must immobilise the limb in the opposite position not across the chest in internal rotation but in a plaster spica in external rotation because otherwise recurrent posterior dislocation will develop

Michaelis L. S "Internal Rotation Dislocation of the Shoulder" *Proc Roy Soc Med.*, 7th Dec 1948
Michaelis L. S "Internal Rotation Dislocation of Shoulder" *J Bone Joint Surg.*, 1950 32-B, 223.

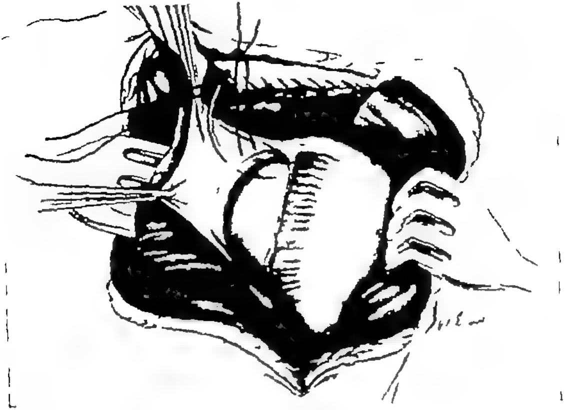

FIG 703
The tissues in front of the neck of the scapula, including labrum periosteum and deep capsule, are stitched to the lateral stump of subscapularis.

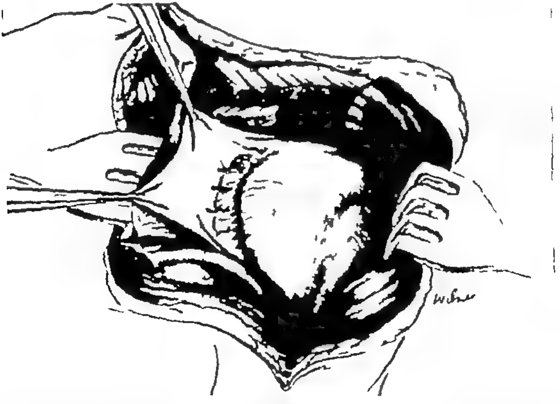

FIG 704
The four or five sutures have been tied while the limb was in internal rotation. The medial part of capsule and subscapularis are then overlapped and sutured to the region of the tuberosity Coraco-brachialis is reattached to the coracoid and the wound is closed. The limb is held in internal rotation for four weeks after operation.

Diagnosis—Backward dislocation of the shoulder is often overlooked.[1,2] The shape of the shoulder may at first seem normal and radiographs in the antero-posterior plane may show no obvious displacement (Fig 781) One important clinical sign is undue prominence of the coracoid process There is loss of normal contour as seen from the side the head of the humerus lying well behind the coracoid whereas normally much of it is in front Flattening of the front of the joint is confirmed by palpation and the head of the humerus can be felt below the spine of the scapula Radiographs in vertical projection[3] show the displacement most readily (Fig 781 inset) but even antero-posterior radiographs of good quality show an abnormal relationship between the humeral head and glenoid The displacement in Figure 782 is obvious by reason of the overlap of shadows but even earlier films of the same shoulder cannot be considered normal when compared with the opposite joint (Figs 783-784) The fit of humerus to glenoid is inaccurate there is a compression fracture of the front of the humeral head and fixed internal rotation deformity is disclosed in the abnormal shadow of the tuberosity

Treatment—The dislocation should be reduced by applying traction and rotating the limb outwards It must be immobilised after reduction in a position of external rotation To put the limb in a sling or to strap it across the chest in internal rotation is to invite recurrence of the dislocation which was produced by internal rotation A plaster spica should be applied with the limb externally rotated in a comfortable position of about 40 degrees abduction with the elbow behind rather than in front of the plane of the trunk Active exercises may be practised after three weeks

Late unreduced posterior dislocation—Being commonly overlooked late operative reduction of the dislocation may be needed but fortunately this is easier than in unreduced forward dislocation and there is less risk to the axillary artery and nerves Through a four inch incision over the top of the acromion and behind it the deltoid origin is stripped from bone and the conjoined tendon of supraspinatus infraspinatus and teres minor is divided half an inch from its insertion the capsule being divided in the same line After replacement of the humerus in the glenoid stitches should be inserted deeply in the stump of capsule and tendons including the labrum and periosteum, and fixed with overlapping or double-breasting to the distal flap of capsule and tendons The limb should be immobilised in plaster in external rotation for about six weeks

RECURRENT FORWARD DISLOCATION OF THE SHOULDER

Until recently the problems of recurrent dislocation of the shoulder were not understood and bewilderment was so great that no less than seventy different operations were described for its cure It was known that recurrent dislocation of other joints arose from failure to immobilise the first injury so that capsular detachments from bone did not heal, but it was thought that the shoulder was different Ordinary dislocations of this joint were supposed to arise from hyperabduction stress forcing the head of

[1] Wood, J I Posterior Dislocation of the Head of the Humerus (reporting three posterior displacements in 11 shoulder dislocations) *United States Naval Med Bulletin*, 1941 39, 532.
[2] Thomas M A Posterior Subacromial Dislocation of the Head of the Humerus" (reporting seven cases, three from total of six thousand shoulder examinations) *Amer J Roentgen.*, 1937 37 767
[3] Warrick C K Posterior Dislocation of the Shoulder Joint *J Bone Joint Surg.*, 1948 30-B, 651

rotation exercises being incapable of stretching the tight anterior capsule and succeeding only in stretching the ligaments at the inner end of the clavicle

RECURRENT POSTERIOR DISLOCATION OF THE SHOULDER

Nearly all injuries of the shoulder joint tend to thrust the head of the humerus forwards but occasionally the force is in the opposite direction and a backward drive with internal rotation displaces the head of the humerus behind the glenoid The pathological anatomy of this injury is the exact converse of that of forward dislocation The capsule is detached with or without the labrum from the back of the joint ; there may be a fracture of the posterior margin of the glenoid , and there is often a compression fracture of the front of the head of the humerus in the antero medial sector This dislocation is sustained from a backward driving force of the internally rotated humerus and after it is reduced the limb must not be immobilised in front of the chest in forward flexion and medial rotation but in a plaster spica in extension and lateral rotation

The displacement has often passed unrecognised—though fixed internal rotation of the limb undue prominence of the coracoid and the radiographic appearance should disclose it (Figs 263 265) Many of these posterior dislocations have been left unreduced and in others failure to recognise the importance of immobilisation in external rotation has caused recurrence [1-6] A typical case-history may be reported After the first injury the patient s shoulder slipped out every time that the limb was abducted in the internally rotated position ; it could always be reduced spontaneously with a loud and painful thud when the limb was rotated externally Operative exposure through a posterior split-deltoid approach with division of the infraspinatus and teres minor tendons one inch from their insertion showed detachment of the posterior capsule with the glenoidal labrum After freshening the exposed bone of the posterior margin of the glenoid the capsule and tendons at the back of the joint were sutured with overlapping and the limb was immobilised for four weeks in a plaster spica in a position of external rotation and a comfortable degree of about 50 degrees abduction Recovery was complete and the patient has since resumed her gymnastic activities (Fig 795)

FRACTURE-DISLOCATION OF THE SHOULDER

One of the most difficult of all shoulder injuries is fracture of the neck of the humerus with inferior dislocation of the humeral head which is usually rotated through 90 degrees the head of the humerus lies almost upside down An attempt should be made to reduce the displacement by applying traction with the limb near the side of the trunk, together with direct pressure in the axilla with the object of tilting the head of the humerus back to its position This sometimes succeeds (Figs 798 799) It is dangerous to adopt the methods described by Bohler and Robert Jones of applying traction in 90 degrees or even 180 degrees of abduction of the limb which tend to

Warrick, C K "Posterior Dislocation of the Shoulder Joint." *J Bone Joint Surg.*, 1948 30-B, 651
Zadik F R. Recurrent Posterior Dislocation of the Shoulder *J Bone Joint Surg* 194 30-B, 531
Hindenach J P R *J Bone Joint Surg* 194 29, 582.
Rowe C R. and Yee L. *J Bone Joint Surg.*, 1944 26, 580.
Bankart A S Bl ndell *Brit J Surg* 193 26, 3.
Watson-Jones, R. Fractures and Joint Injuries. Edinburgh E. & S Livingstone 3rd ed. 194.

Fig 782

Posterior di location of the shoulder sustained during convulsive therapy three months earlier The displacement is evident even in the antero-posterior radiograph because there is overlap of shadows of humerus and glenoid. The axial view makes it obvious that there is posterior dislocation of the joint with fractures of the front of the humerus and the back of the glenoid.

Fig 783

Fig 784

Late unreduced posterior dislocation of shoulder

Radiographs of the same case as in Figure 782 taken at the time of injury The antero-posterior view of the injured shoulder (Fig 783) compared with the normal shoulder (Fig 84) should make the surgeon suspect *posterior* dislocation. This was not recognised so that although the dislocation was reduced, the limb was immobilised across the chest in internal rotation and of course, it recurred Operation reduction with capsular plication was performed after three months. Despite the fractures, normal function was regained, and there was no recurrence of dislocation

Fig 795

Recurrent Posterior Dislocation of the Shoulder

Every time that the patient abducted the internally rotated shoulder the joint dislocated She could dislocate it at will by abducting the limbs in internal rotation; and no less easily she could replace it by externally rotating the joint; it went in with a painful thud. The antero-posterior radiograph taken while the joint was dislocated shows incongruity of the surfaces the axial view confirms that it is a backward displacement. Complete relief from the disability was gained by reattaching the fibro-cartilage and double-breasting the capsule over the back of the joint

the humerus *downwards* through a tear in the capsule which would heal after reduction of the displacement whether or not the joint was immobilised whereas epileptics in their fits and Rugby football players in their games who fell backwards on the point of the elbow behind the trunk, drove the head of the humerus *forwards* and thus sheared the glenoid fibrocartilage from bone—an injury which it was said could *not heal no matter what the* primary treatment might be Thus we were taught that ordinary dislocations of the shoulder needed no immobilisation because capsular tears would always heal whereas recurrent dislocations were destined to be recurrent from the beginning because fibrocartilage could not reattach itself to bone [1 2]

This was all wrong The fact is that there is no essential difference between dislocations of the shoulder and dislocations of other joints [3] In all such injuries capsule is torn from bone and if the first displacement is reduced and the joint is immobilised the tear will heal but if a recently dislocated joint *is not immobilised the capsular detachment may not heal and recurrent dis*location then occurs—and this is no less true of the shoulder than of the ankle hip elbow the joints of the cervical spine or the carpal joints of the wrist

Pathological anatomy—Acute anterior dislocation of the shoulder does not arise solely from hyperabduction stress forcing the head of the humerus *down through a capsular tear such a mechanism of injury is much less* frequent than falls on the outstretched hand violent external rotation movements forcible extensions of the abducted arm or falls backwards on the point of the elbow, all of which drive the head of the humerus forwards The pathological anatomy of acute dislocation of the shoulder consists nearly always in *detachment of capsule from the front of the glenoid with or* without the labrum sometimes it is a detachment of capsule from its lateral insertion to the humerus together with a tear of the subscapularis [4] seldom is it a tear of the capsule itself without detachment from bone

Furthermore and again in common with other joint injuries fractures of bone are often sustained at the time of the first dislocation As the head of the humerus is driven forwards over the anterior margin of the glenoid a compression fracture of the postero-lateral sector of the humeral head may be sustained There may also be a fracture of the anterior margin of the glenoid These bone injuries are themselves sources of recurrent dislocation *if the first injury is not properly immobilised It is obviously much easier* for the head of the humerus to slip forwards repeatedly over the anterior margin of the glenoid from any external rotation movement if there is not only unhealed detachment of capsule from the front of the glenoid but also wedge-shaped compression in the back of the humeral head (Figs 785-786) *and if the compression fracture is deep enough the head of the humerus may* displace forwards even if the capsular attachment is intact the subluxation then being entirely intracapsular The fact is that in recurrent forward dislocation of the shoulder there is unhealed detachment of the anterior capsule with or without the labrum in 87 per cent of cases and compression *fracture of the back of the head of the* humerus in 82 per cent [5] Either lesion in itself may cause recurrence but usually both are present

Bankart A Blund B *Brit med J* 1923 2, 1132.
Bankart A S Blund B *Brit. J Surg* 1938 26, 23.
Watson-Jones R Editorial, *J Bone Joint Surg* 1948, 30-B 6.
Eyre-Brook A L "Recurrent Dislocation of the Shoulder" *J Bone Joint Surg* 1948 30-B, 39
Adams, J C [illegible] Recurrent Dislocation of Shoulder *J Bone Joint Surg*, 1948, 30-B, [illegible]

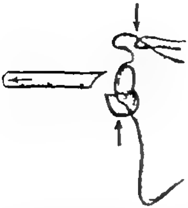

Fig 796

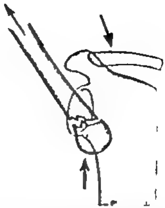

Fig 797

Traction to reduce fracture-dislocation of the shoulder in right-angled abduction as described by Bohler (Fig 796) or even in hyperabduction as described by Robert Jones (Fig 797) may imperil the brachial vessels and nerves which are already stretched over the displaced head of the humerus.

Fig 798

Fig 799

Fracture-dislocation of the shoulder before and after reduction Note that before reduction the head of the humerus is almost upside down. This fracture-dislocation was reduced by traction applied to the limb by the side of the trunk—not in right-angled abduction or hyperabduction—together with direct pressure beneath the head of the humerus.

Once such a dislocation has been sustained, and not been correctly treated by immobilising the limb by the side of the trunk with protection from every external rotation movement recurrence is to be expected from increasingly simple activity. Any quick abduction-external rotation of the limb may displace the head of the humerus forwards putting the arm through the sleeve of a coat reaching behind the back of the neck rubbing down with a bath towel held behind the trunk, raising a racket to serve at tennis, swimming with an over arm stroke playing the upswing of a golf drive reaching for a grip in rock climbing or signalling through the window of a car—all these movements are quoted from case histories. Sooner or later dislocations recur even while the patient is asleep when movements of

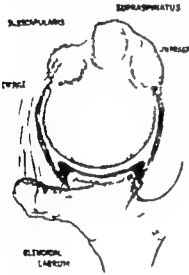

Fig 85

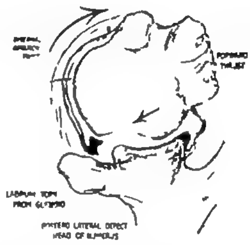

Fig 86

Diagram showing the position of the glenoidal labrum in the normal shoulder (shaded in black, Figure 85) and the displaced position in recurrent dislocation where as a rule there is also traumatic compression of a sector of bone in the postero-lateral aspect of the humeral head (Fig. 86). In these circumstances the head of the humerus slides forwards whenever the limb is externally rotated.

the limb are unguarded. Many patients have sustained twenty forty, sixty or even one hundred dislocations. I am not sure what the record may be but it must be in the region of from one to two hundred. Moreover many of these victims while not actually dislocating the joint suffer repeated discomfort day by day and hour by hour from momentary subluxation which though spontaneously reduced causes sickening pain.

Clinical diagnosis—The diagnosis of recurrent dislocation of the shoulder is made easily from the history but when there is doubt confirmation may be gained by abducting the arm externally rotating it to the right angle and then displacing the elbow backwards. It is not really necessary to dislocate the joint—the patient's apprehension at the moment that it is about to be displaced is enough—but the surgeon should be ready to replace the humerus promptly if in performing this manœuvre he does dislocate it. All that needs to be done is to apply steady traction from a grip round the patient's elbow (preferably using the left hand round the elbow if the

compress the already stretched brachial vessels and nerves and may cause irreparable damage (Figs 796 797) If manipulation by the Hippocratic method fails it is better to expose the bone through the delto pectoral approach and tilt the head of the humerus back into its proper relationship with the shaft It is true that a completely detached humeral head may degenerate and die because of avascular necrosis and for this reason if open operation is needed every effort should be taken to preserve soft tissue attachments but even if the head of the humerus does undergo avascular degeneration primary replacement has still been worth while Arthrodesis of the joint will permit reasonable function whereas the flail shoulder that results from early excision of the head of the humerus presents serious problems of treatment The principles of management of fracture-dislocations of the shoulder in which fracture of the neck is accompanied by downward dislocation of the head of the humerus should therefore be 1) replace the displacement by the Hippocratic method of traction on the limb near the side of the trunk 2) if this fails replace the head of the humerus through an open exposure, 3) if painful arthritis develops from avascular degeneration of the humeral head perform an arthrodesis of the joint, 4) resist the temptation to excise the dead head which causes a flail and almost useless joint

Downward Subluxation of the Head of the Humerus after other Injuries of the Joint

Fractures of the neck of the humerus and other injuries of the shoulder joint are not uncommonly associated with temporary downward subluxation of the humeral head developing some weeks after injury especially when the arm has been suspended in a collar and cuff sling The downward displacement of the head of the humerus may be very considerable and it has often caused alarm—though the fact is that it arises only from dependence of a heavy limb at a time when muscles are hypotonic The situation was made clear by the studies of T J Fairbank [1] who demonstrated the degree of subluxation that was possible from traction on the normal shoulder joint of an anæsthetised individual whose muscles were relaxed When a fracture of the humerus is suspended in a collar and-cuff sling subluxation of the head of the humerus is to be expected It is of course better to prevent it by supporting the limb in a triangular sling—but if it arises there need be no alarm The downward subluxation will correct itself when muscle exercises are resumed The worst outcome is that which threatened one patient whose radiographs are shown in Figures 800 801 This fracture of the neck of the humerus had been slow in uniting and because radiographs showed downward subluxation of the head of the humerus as well as unsound union of the fractured neck it was proposed to operate and arthrodese the joint! Never was surgical misunderstanding more ready to lead to surgical misadventure Clinical tests showed that the fracture was sufficiently united to begin active exercises which cured the subluxation—and to-day the patient has a normal shoulder with a normal range of movement Be not disturbed by temporary downward subluxations of the head of the humerus in fractures and other lesions which arise solely from muscle hypotonicity and are cured by active exercise

[1] Fairbank, T J "Fracture-subluxation of the Shoulder" *J Bone Joint Surg.*, 1948, 30-B 454.

patient's right shoulder is displaced and the right hand round the elbow if the patient's left shoulder is displaced) then with the other hand in the axilla pressing the humeral head outwards while the limb is gently rotated inwards No anæsthetic is required, firm steady traction with correct manœuvring will succeed

Radiographic diagnosis—The compression fracture in the back of the head of the humerus which arises from impact against the anterior margin of the glenoid and is increased in depth and size with every recurrence of dislocation until it may be a defect of at least one-quarter of the humeral head is seldom disclosed in routine antero-posterior radiographs of the joint Radiographs should be taken with the limb in various positions of internal rotation The defect is most often demonstrated in profile when antero-posterior radiographs are taken with the humerus in 60 to 70 degrees of internal rotation (Figs 787 789)

Operative treatment—Why is it that no less than seventy different operations have been described for the treatment of recurrent dislocation of the shoulder success having been claimed for nearly all? The procedures have included muscle transplants tendon transpositions capsular reinforcements displacements of the biceps tendon fascial slings transplantations of the peroneus check ligaments divisions of the latissimus dorsi lengthening of the coracoid process bone pegs into the glenoid insertion of staples driving of screws and a host of other operations It would be laborious to describe them all but the literature is summarised[1 ''] The fact is as I said at a clinical meeting in the Royal Society of Medicine long ago when no doubt I was too young to have said it that the only factor common to these procedures is a bloody dissection through an anterior approach the operations succeeded because they limited external rotation movement of the joint just as Hippocrates succeeded two thousand years before when he applied a white-hot cautery to the front of the shoulder and then bound the arm to the side both night and day for so would the cavity into which the humerus is mostly displaced be best cicatrised up and cut off If external rotation movement is sufficiently controlled the head of the humerus with its posterior defect cannot slip forwards over the anterior margin of the glenoid from which the labrum or capsule have been detached

FIG. 800

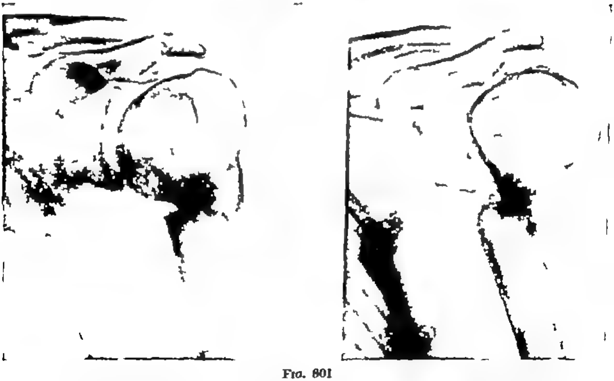

FIG. 801

Downward subluxation of humerus from gravity after fracture of the neck of the humerus or other injuries

A surgeon proposed to arthrodese this patient's shoulder because when he saw him four months after a fracture of the neck of the humerus he thought that it was a fracture-dislocation with non-union of the fracture and non-reduction of the dislocation (Fig. 800). As a matter of fact the fracture was clinically united (the callus being no more porotic than the rest of the humerus) and the "dislocation" was a simple consequence of muscle atrophy and dependence of the limb. The collar-and-cuff sling was discarded and active exercises were practised; thus bone atrophy and muscle atrophy were both cured so that the fracture consolidated and the subluxation was corrected. To-day the patient has a normal limb (Fig. 801).

FIG 787

FIG 788

FIG 789

The compression defect in the postero-lateral aspect of the humeral head arising from impaction against the anterior margin of the glenoid in recurrent dislocation of the shoulder joint is shown only when radiographs are taken with the limb rotated inwards through 60 or 70 degrees (Fig 787). Radiographs in neutral rotation (Fig 788) and in external rotation (Fig 789) show no abnormality The compression fracture may also be obscured if the limb is internally rotated too much—it should be rotated inwards only 60 degrees.

This is the essential basis of any operation for recurrent dislocation of the shoulder—the range of external rotation movement must be restricted.[1]

Nicola operation—The operation described by Nicola in which the biceps tendon was cut below the bicipital groove the proximal end being threaded through a drill hole in the head of the humerus so that the tendon then served as an intra articular ligament rather like the ligamentum teres,

[1] Watson-Jones, R. Note on Recurrent Dislocation of the Shoulder *J Bone Joint Surg* 1948, 30-B, 49

CHAPTER XIX

INJURIES OF THE ARM

Fractures of the Shaft of the Humerus

Fractures of the shaft of the humerus may be spiral from rotational stress oblique or transverse from angulatory stress or comminuted from direct crushing injury There is seldom serious displacement, and few injuries are more easy to treat The muscles of the arm as compared with those of the thigh are short and relatively weak and there is little tendency to over riding of the fragments Indeed one of the few dangers of treatment is that distraction may cause slow union Treatment by skeletal traction from an olecranon pin should therefore be avoided no matter whether used in association with a splint or frame or by the overhead suspension favoured in Latin American countries where the patient lies recumbent with the unsplinted limb elevated to the side of the head and suspended by weights from the olecranon pin [1]—an unpleasant treatment for so simple a fracture

Almost equally unsatisfactory is the hanging cast technique used widely in the United States *in which a heavy plaster cast from the wrist to the axilla* sometimes even weighted with lumps of lead is slung and suspended from the neck [2] It is said that the weight of the cast is needed to maintain proper alignment but I do not know of any surgeon who keeps these patients standing and walking all night as well as all day and if traction is needed in the daytime why is it not needed at night? The fact is that it is not needed at all. Traction is harmful and it delays union All that is required is to keep the fragments in proper alignment by local splints or plaster slabs the limb being supported in a triangular sling for about five or six weeks

The splintage need not be extensive Unlike many other shaft fractures where the joints above and below the broken bone must be immobilised to prevent shearing and rotational stresses union of most of these fractures is so rapid that it is difficult to stop The blood supply is rich the formation of callus is vigorous and fractures heal quickly despite the handicap of imperfect immobility Thus the standard treatment of recent fractures of the shaft of the humerus should be the application of two or three short gutter splints strapped round the arm or a plaster slab on each side of the limb together with the support of a triangular sling for about five weeks

After such emphasis that treatment is usually easy it must be added that occasionally there is indolence—especially in transverse fractures with relative avascularity of the distal fragment comminuted fractures and fractures from shell wounds where many bone fragments may be dead and fractures in which ill advised treatment by heavy traction has delayed union The situation is then different There is no longer vigorous callus *formation* with rapid healing despite the handicap of imperfect immobility Repair

[1] Zeno L "Fractura supracondilea del humero." *Rev ortop traumat.*, 1934 3, 4-2.
[2] Caldwell, J A. *Surg Gyn. Obstet.* 1940 70 421

failed in at least 30 per cent of cases The ligamentous check was not strong enough to meet the double lesion of labral detachment and fracture of bone especially if the patient engaged in strenuous recreational activity The tendon often ruptured within the joint

Bankart operation *—An approach is made through the delto-pectoral cleft The coracoid process is divided and the tip of the bone together with the muscles attached to it—pectoralis minor and the short head of biceps—is retracted downwards and inwards The subscapularis is divided rather less than one inch from its insertion and the muscle is retracted inwards Division of capsule in the same vertical line then discloses the articular

Fig 790

Recurrent dislocation of the shoulder in which Nicola's transplant of the biceps tendon had failed (see the tendon passing into the head of the humerus). The retractor is lifting tissues from the anterior glenoid margin and showing the detachment of labrum and capsule which occur in nearly all recurrent dislocations; there is also a defect of bone in the postero-lateral sector of the head of the humerus.

surface of the humerus The upper end of the externally rotated humerus must be pulled laterally by an assistant to expose the anterior margin of the glenoid fossa The exposure is by no means easy but it can be helped by inserting a skid retractor in front of the humeral head and behind the glenoid fossa thus gently levering the humerus away from the glenoid When it is seen that the capsule and labrum are detached the eburnated bone margin should be freshened with an osteotome, one strong mattress suture of silk or catgut being then passed *through drill holes in the bor* [illegible] *the* labrum and capsule and tied securely [illegible] drill [illegible] angles to the shaft of the instrument may [illegible] the [illegible] Some surgeons do not drill the glenoid [illegible] use a [illegible] ch

* *A. S. Blundell Bankart*—For the sak of accuracy [illegible] y accord [illegible] in the literature let it be recorded firmly that there never was a [illegible]

is slow and it may be many weeks or months before the fracture unites Indeed unless the bone is protected from shearing and rotational stresses it will not unite at all (Figs 22 24 and 63-66) The complete and rigid *immobilisation of a plaster spica may be needed for a long* period—usually from ten to fifteen weeks

Ironically the treatment of recent fractures of the shaft of the humerus being so easy the treatment of un united fractures is most difficult and it has threatened to be one of our greatest failures The last patient I treated

Fig 802

Plaster slab for fracture of the shaft of the humerus. It is usually enough to place a pad of wool in the axilla and support the limb in a sling but if there is a persistent tendency to outward angulation of the fragments, the limb may be placed on a frame in 40 to 50 degrees of abduction (inset).

for this disability came from Israel after having had sixteen operations in thirteen years *the one before that came from Cumberland after submitting* to fourteen operations in ten years—the fractures were still un united The utter indolence of an un united fracture demands not only freshening of the bone surfaces with the insertion of a bone graft but complete protection from every shearing and rotational stress and this is difficult to attain in the humerus Even when a plaster spica is applied the patient can soon shrug his limb up and down in and out and to and fro and the support of a plaster spica must be supplemented by internal fixation—preferably that of an intramedullary nail

Treatment of recent fractures of the shaft of the humerus—Three padded gutter splints should be chosen—one long enough to extend from the acromion to the lateral epicondyle of the humerus a shorter one to lie behind the arm and a still shorter one to be placed from below the axilla to the medial epicondyle The splints are bound firmly in position by adhesive strapping with a large pad of wool in the axilla the limb being supported in a triangular sling Alternatively a slab of plaster may be applied from below the acromion down the outer side of the limb round the point of the elbow

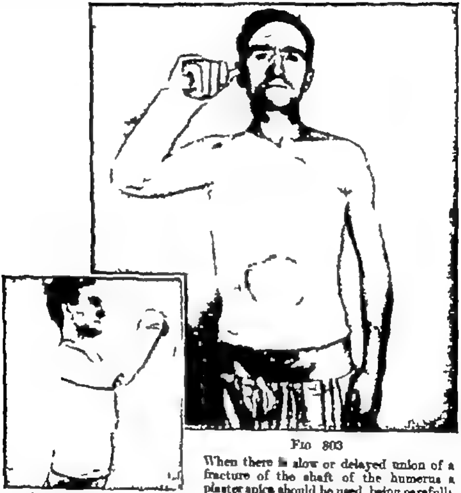

Fig 803

When there is slow or delayed union of a fracture of the shaft of the humerus a plaster spica should be used being carefully moulded round the shoulder and trunk as well as round the arm and elbow

and up the inner side to near the axilla it is bandaged in position and again the limb is supported in a sling with an axillary *pad of wool* If radiographs show that there is lateral angulation of the fragments the size of the pad of wool between the arm and chest wall should be *increased* or the limb may be rested on a frame in 40 or 50 degrees of abduction (Fig 802) Every few days as swelling subsides the bandages *supporting the splints* or plaster slabs should be tightened Finger and wrist exercises are to be practised from the beginning After about five weeks clinical tests usually show that early union has taken place and the splints or plaster casts may be discarded although the support of the triangular sling *may be maintained* for two or three weeks longer while active exercises of the elbow and wrist joints are practised at regular intervals Recovery is *usually* complete within two or three months

supination so that a complete cuff is separated. Only then should the bone be cut with a sharp osteotome through the neck of the radius immediately above the orbicular ligament. The cuff of periosteum should be replaced over the raw stump of the radial neck (Figs 817 818). In this way ossification of the post-operative hæmatoma with the formation of a mass of bone which may block movement is prevented. After operation the limb should be rested in a sling for two or three weeks. Movements should be regained by active exercise alone; there is no need for passive stretching, forcible mobilisation or manipulation. Many months may elapse before the final range of extension movement is regained but the more anxious and hasty the surgeon is the more certainly will he jeopardise recovery.

FRACTURE OF THE HEAD OF THE RADIUS IN CHILDREN

Displacement of the Upper Radial Epiphysis or Greenstick Fracture of the Neck of the Radius

A fall on the outstretched hand which impacts the head of the radius against the capitellum is the cause of fracture of the head of the radius in adults and of displacements of the upper radial epiphysis in children. The displaced fragment includes the epiphysis, the epiphyseal line and a triangular fragment from the diaphysis. In some cases the line of injury is rather lower and it is more accurately described as a greenstick fracture of the neck of the radius. The head is displaced outwards and slightly forwards and as a rule it is also tilted so that its humeral articular surface faces outwards. The proof that this tilt arises from impact against the capitellum by valgus strain of the joint is found in the rupture of the medial ligament or avulsion of the medial epicondyle often associated with it.[1] Slight lateral displacement without angulation and with the articular surfaces still parallel is relatively unimportant; it does not interfere with movement of the joint and gradual remodelling of the bone will mask even the radiographic evidence of displacement. But if the head of the radius is tilted it presents an angular margin for articulation with the capitellum instead of the normal smooth and slightly concave surface. The regenerative powers of growing bone are not equal to the correction of such an angulation and inequalities of the articular surfaces cause repeated traumatisation of the joint with permanent limitation of extension movement. After correction of the displacement recovery is usually complete within three or four months whereas with uncorrected angulation there may still be considerable limitation of extension movement after several years.

Treatment—*Manipulative reduction*—It is often possible to correct the displacement by extending the elbow, adducting the forearm and pressing firmly over the front outer aspect of the epiphysis.[2,3] After correction the joint should be immobilised in plaster at the right angle or if necessary in the fully extended position. The surgeon must not be satisfied with the reduction unless alignment of the fragment is normal and the articular

[1] Dunlop, J. "Separation of Medial Epicondyle of Humerus" (case with displaced upper radial epiphysis). *J. Bone Joint Surg.* 1935, 17, 584.
[2] Patterson, R. F. "Fractures of the Neck of the Radius in Children" (manipulative reduction). *J. Bone Joint Surg.*, 1934, 16, 695.
[3] Jeffery, C. C. "Fractures of the Head of the Radius in Children." *J. Bone Joint Surg.* 1950, 32-B, 314.

Treatment of fractures of the shaft of the humerus with slow and delayed union—If at the fourth or fifth week it is found that union has hardly begun and the fragments can be moved almost as freely as at the time of injury the surgeon must beware This is a case of *slow or delayed union which* threatens to fail unless immobility is much more complete A plaster spica must be applied carefully moulded not only round the forearm elbow and arm but more especially round the shoulder and trunk, all shrugging movements of the shoulder joint must be controlled (Fig 803) It may be necessary to continue such immobilisation in plaster for ten or fifteen weeks

Treatment of un-united fractures of the shaft of the humerus—If non union of the fracture is established, with eburnation and sclerosis of the fragments, operative treatment is essential. It is not enough to use intramedullary pegs it is not enough to expose the bone and insert a miserable inlay graft it is not enough to use the Phemister onlay graft of bone without screw fixation—these are the procedures that have threatened to make un united fracture of the shaft of the humerus one of our greatest unsolved problems The difficulties of external protection by plaster spicas and frames are so great that sound internal fixation is imperative A single or dual onlay graft with screw fixation will often succeed *but it is still better to use an* intramedullary nail with transplantation of iliac cancellous bone chips to the site of fracture

The bone should be exposed through a lateral incision the musculospiral nerve first being identified and held aside with tapes The nerve lies so close to bone that it is often contused by the initial injury and by the time that non union has developed with fibrosis and scarring of tissues the proximity and adhesion of the nerve to one or other fragment is such that it is in peril Even if exposure of the nerve is difficult engaging perhaps thirty or more minutes of the surgeon s time it is better to identify and retract it before dealing with the bone

The fragments are then exposed and the surfaces are freshened by excising the dense eburnated bone The *medullary canal of both fragments* is opened by drilling from the site of fracture It is wise to have a special set of long handled drills each equal in diameter to that of an intramedullary nail successively wider drills are introduced until one engages snugly but not too tightly The corresponding nail is then selected and driven through a separate short incision through the greater tuberosity of the humerus and down the proximal shaft fragment When the nail appears *at the fracture site the fragments must be held carefully in correct* alignment while the nail is driven on to the distal fragment The correct length of nail should have been determined before operation either by measuring radiographs specially taken without magnification or by taking an ordinary film of the humerus with a nail of the estimated length laid alongside so that the magnifications are the same

Iliac bone chips are then cut from the ilium and impacted into the site of fracture between the main fragments and around them *At the* end of the operation the immobility should be so complete that there cannot be any doubt that the fracture will unite—but nevertheless a plaster *spica should still be applied and kept in position until union is sound* (Figs 804 805) It does no harm to make assurance doubly sure

surfaces of radius and capitellum are strictly parallel If this has not been achieved by manipulation operative reduction is advisable

Operative reduction—Through a short incision the head of the radius is exposed A sterile pad of gauze is placed over the head of the bone and with thumb *pressure it is pushed upwards and backwards* (Figs 819-820)

FIG 819

Fracture of the neck of the radius in a child, or "displacement of the upper radial epiphysis. *The head of the radius is tilted forwards and outwards.*

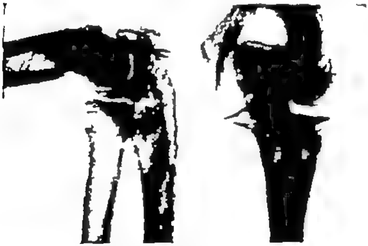

FIG 820

The displacement of the upper radial epiphysis has been *corrected by direct pressure on the bone after open exposure* There is no need whatever for internal fixation by pinning, nailing or pegging the head and certainly not for replacement with a metal or plastic prosthesis.

As a rule the periosteum of the neck is not ruptured and the bone injury *is of the greenstick variety so that it is easily moulded into position* Reduction is quite stable and it is quite indefensible to suggest that bone pegs or nails should be driven through the articular surface of the head of the radius through the neck. After operation a plaster cast should be applied from below the shoulder to the metacarpal heads and im*mobilisation is continued for three weeks* Movements are then regained

Despite the fact that un united fractures of the shaft of the humerus have threatened to be one of our greatest failures there is no reason why it should be so We have failed hitherto because we relied too much on imperfect methods of fixation in a fracture so indolent that every possible

Fig 804

Fig 805

This patient sustained a fracture of the shaft of the humerus ten years before and fourteen operations had been performed without success—the fracture was still un united (Fig. 804) The bone ends were freshened Iliac bone chips were implanted, and intramedullary nail fixation was used to supplement the protection of a plaster spica for three months. This technique of cancellous bone grafting with intramedullary nail fixation will be used increasingly for un united fractures.

protection from shearing and rotational strains was needed The grafting methods of the past and the plaster spicas and frames as usually applied did not provide this protection Cancellous bone grafting with intra medullary nailing and the external support of a plaster spica does provide it Failures persisting after sixteen and eighteen operations should be no more than unhappy memories of the past

by unaided active exercise Within a few months there will be a normal range of flexion and extension movement although radio ulnar movement often remains slightly limited from periosteal new bone formation round the neck of the radius

FRACTURE OF THE CAPITELLUM

The frequent association of fracture of the head of the radius with injury to the cartilage of the capitellum has already been mentioned The radius is driven upwards and forwards by a fall on the outstretched hand and it delivers a shearing blow to the front of the capitellum which may injure

Fig 821

Fig 822

Two examples of chip fracture of the capitellum. In the injury shown in Figure 821 a crack fracture of the head of the radius became obvious in later X rays. In Figure 822 the capitellar fragment is rotated and is back to front These fragments involve only a small part of the articular surface and have no blood supply they should be excised.

the bone as well as the articular cartilage[1] Any size of fragment may be broken off but it is convenient to distinguish three degrees of injury bruising of the articular cartilage of the capitellum chip fracture of the capitellum where small fragments of cartilage and bone are completely detached and fracture of half the capitellum and part of the trochlea

Bruising of the articular cartilage of the capitellum—This injury of articular cartilage is responsible for the limitation of extension movement that is sometimes unavoidable in fractures of the head of the radius It may also occur as an isolated injury without associated fracture of the head of the radius causing localised avascular necrosis and osteochondritis dissecans[2]

Chip fracture of the capitellum—If the detached fragment consists only of cartilage it is not disclosed by radiographic examination and the lesion may be discovered only when the joint is opened for treatment of the associated fracture of the radial head The fragment may consist largely of cartilage but also include a thin flake of bone In other cases cartilage

[1] Milch, H. "Unusual Fractures of the Capitellum Humeri." *J Bone Joint Surg.*, 1931 13, 88—
[2] Fairbank, H A. T "Osteochondritis Dissecans. *Brit J Surg* 1933 21 6—

CHAPTER XX

INJURIES OF THE ELBOW

The danger of increasing the stiffness of injured elbow joints by passive stretching and forcible manipulation was known to Hugh Owen Thomas and Robert Jones more than half a century ago[1 2] but even in recent years a vigorous campaign was needed to stop this harmful practice A brilliant violinist went to Vienna to perfect her technique and sustained a dislocation of the elbow after two weeks she swung from beams three times every day to force the joint straight and one year later had no more than 40 degrees of movement—she never played the violin again A sea-captain sustained a minor fracture of the head of the radius and paraded the deck every morning for one hour carrying a typewriter with the object of straightening the limb—there was permanent limitation of movement A boy with simple traumatic synovitis of the elbow was treated twice daily for nearly six months by massage and stretching until he was in tears—the range of extension movement after two years is shown in Figure 806 Parents sometimes encourage their children with elbow joints stiff from injury to carry buckets of water or bags of sand only to find that the stiffness is increased Recently I saw a child whose injured elbow had been stretched every day by a masseuse who congratulated him whenever she elicited a wince of pain—what a grave misunderstanding of treatment!

FIG. 806

Range of extension movement two years after simple strain of the elbow The serious stiffness arose solely from passive stretching

No child with an injured elbow should be referred to a physiotherapy department There is nothing a masseuse can do that the child cannot do for himself but there are few who when faced every day with a stiff joint that does not seem to be recovering can resist the temptation to use force It is better not to submit physiotherapists to this temptation From the beginning it should be explained that although recovery may be slow it will be gained most rapidly by the unaided activity of the patient The range should be measured month by month because movement is often restored so slowly that only by regular measurement can the gain be recognized and the anxiety be allayed If dislocations are reduced

[1] Jones Robert "On Injuries to the Elbow Joint." *Clin. J.*, 1904 25, 17
[2] Jones Robert "Injuries about the Elbow in Children." *Brit. med J.*, 193_ 1 39

by operative repair[1] especially when the fracture is high or the olecranon fragment is comminuted

Manipulative treatment—The range of retraction of the triceps after a fracture of the olecranon is limited and the detached fragment may lock in the olecranon fossa it is pulled no further than to the position it occupies when the elbow is extended fully Moreover it seldom tilts and it is not always covered by a curtain of living fibrous tissue Very often therefore a fractured olecranon can be reduced perfectly by extending the elbow fully and pressing firmly over the fragment so that it is pushed forwards and downwards into the angle from which it has been displaced Displacement of the olecranon epiphysis is an exactly comparable injury and it is easily reduced by manipulation An anterior plaster cast is applied

FIG. 827

FIG. 828

Fracture of olecranon treated by manipulative reduction, and immobilisation in full extension. The fracture is firmly united and there is normal movement

from below the shoulder to just above the wrist encircling strapping over a felt pad on the point of the elbow maintains pressure on the olecranon fragment Radiographs should be taken at once because conservative treatment is justified only if the fragments are in absolute contact and accurate apposition Even a slight gap suggests that capsule and periosteum may be interposed so that operative reduction is necessary If a perfect position has been achieved immobilisation should be continued for five weeks throughout which time exercises of the fingers and shoulder are practised The limb is elevated at intervals to prevent gravitational œdema of the fingers and hand Union is then tested clinically and if it is firm elbow movements are practised There must not be passive stretching at any time

Operative reduction—If manipulation fails to restore close apposition of the fragments and a smooth joint surface operative reduction is needed A hole should be drilled transversely in the distal fragment and a suture of

[1] Naughton Dunn Operation for Fracture of Olecranon. *Brit. med. J.*, 19[illegible], 1, 14

and fractured bones are replaced a full range of movement will indeed be regained provided only that passive force painful stretching and repeated manipulation are avoided

Traumatic synovitis of the elbow joint—Minor strains and contusions often cause traumatic synovitis of the elbow joint in children Radiographs show that there is no bone injury but the joint is tender and swollen, and movements are painful The limb should be rested in a sling for about ten days

Tennis elbow—The condition known as tennis elbow arises from strain of the fibres of the common extensor tendon at its origin from the lateral epicondyle of the humerus In tennis players this is usually the consequence of a mistimed backhand stroke When the forearm is semi pronated and the muscles are tensed a fast ball hits the racquet more quickly than was expected and sudden flexion of the wrist stretches the extensor muscles of the forearm at their epicondylar attachment Thus the injury is often sustained from one sudden movement but it may arise also from a series of minor pronation supination strains in those whose work demands hammering screwing ironing or wringing The patient finds it difficult to turn a door knob hold a teapot or grasp any weight in the semi pronated position of the limb There is tenderness on pressure over the lateral side of the joint immediately below the epicondyle Pain is often referred to the forearm and it is increased by the clinical test of lateral strain of the elbow with adduction of the forearm especially in the pronated position

FIG 807

Calcification of the common extensor tendon of the forearm causing symptoms like those of tennis elbow

Conservative treatment—There is seldom complete rupture of the tendinous fibres and the symptoms usually disappear if the limb is rested for a few days in a sling and the particular industrial or recreational activity that was responsible is avoided Local strapping and pressure pads may be useful It has been suggested that the wrist should be immobilised in a cock up splint diathermy and radiant heat have been used injection with novocaine has been tried—but none of these measures are of proved benefit and some make it worse The best treatment is to wait for the natural cure which is nearly always complete although sometimes slow [1]

Manipulative treatment—Manipulative treatment has been advised Mills [2] extended the elbow with the forearm pronated and then flexed the wrist and fingers Many bone-setters adducted the forearm on the arm

[1] "Tennis Elbow—Collective Review" *Int. Abstr Surg.*, 1938, 67 1 6.
[2] Mills, G P "Treatment of Tennis Elbow" *Brit. med J.*, 1928 1 12, and 1937 2, 212

catgut or stainless steel wire is passed, to be crossed obliquely over the superficial surface of the proximal fragment and through the triceps insertion (Fig 820) If the proximal fragment is large enough a second drill hole may be made through it and the catgut or wire is then passed through both drill holes and tied as a square stitch The elbow is immobilised at or just below the right angle by a light plaster slab for five weeks Subsequent treatment is the same as after manipulative reduction

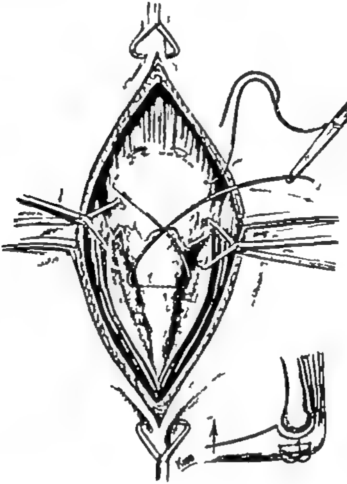

Fig 820

Operation for reduction and suture of fracture of olecranon. By crossing the stitch over the back the fragments are pressed firmly together when the elbow is flexed. A simple square stitch may also be introduced (inset).

Excision of the olecranon and repair of the triceps—The alternative operation especially suited to high fractures separating a smaller fragment and to comminuted fractures in older patients whose joints stiffen more readily is excision of the fragment and repair of the tendon The essential part of this operation is not the excision of the olecranon but the repair of the triceps tendon The fragment is shelled out by close dissection Strong mattress sutures are passed through the triceps guided through a drill hole in the ulna and securely tied Additional fixation may be secured by suturing the triceps tendon to muscles and fascia on each side of the ulna Some surgeons prefer

With the elbow extended and one of the manipulator's hands over the inner side of the joint and the other over the outer side of the lower forearm a sharp inward jerk was performed first in supination and then in pronation [1] Having tried all these manipulations in many patients I am not at all sure that any have hastened the natural and spontaneous cure

Operative treatment—If relief is not gained quickly from simple rest the best treatment is to make a short incision over the lateral aspect of the joint and detach the common extensor origin from the epicondyle There is no need to search for an abnormal bursa which seldom if ever exists [2] Bankart in describing the operation said "You make an incision and scratch like a hen"—he was in fact dividing the common extensor tendon After operation the tendon heals with slight lengthening and the symptoms are therefore relieved It should be noted however that occasionally there is pathological calcification similar to that often seen in the supraspinatus tendon of the shoulder, and in these rare cases the calcareous deposit should be evacuated [3] (Fig 807)

FRACTURE OF THE HEAD OF THE RADIUS

Fracture of the head of the radius is not the trivial injury that it might seem to be Formerly it was thought that cracks in the bone and separations of marginal fragments were minor injuries sustained from glancing blows, but it was difficult to explain the prolonged incapacity and serious limitation of extension movement that so often remained Although it was recognised that severe fractures of the radial head might interfere with radio ulnar movement there seemed no reason why apparently trivial marginal fractures should cause permanent limitation of extension movement Actually these fractures are not caused by glancing injuries across the side of the joint but by falls on the outstretched hand which force the joint into the valgus position impact the radius against the capitellum and comminute the radial head to a more severe degree than is usually disclosed in radiographs The articular surface of the capitellum is contused its cartilage may be detached with exposure of raw areas and fragments of bone may even be broken off as loose bodies Moreover valgus strain at the moment of impact often subluxates the joint momentarily with consequent tearing of the medial collateral ligament or avulsion of the medial epicondyle Fracture of the head of the radius is never a localised injury it is an injury of the radius together with injury of the capitellar surface of the humerus and all structures on the medial side of the joint sometimes including even the ulnar nerve

The extent to which radiographic examination may conceal the true extent of injury is demonstrated in Figures 808-810 The radiographs seem to show a simple marginal fracture of the head of the radius with minimal displacement and yet when the bone was exposed at operation it was obvious that the radial articular surface was seriously damaged and that there was impaction of a fragment of the capitellum between the fragments of the radial head Can there be wonder with such destruction of joint surfaces

[1] Barker H "Demonstration to British Orthopaedic Association." *Brit. med J.*, 1926, 2, ...
[2] Osgood R B "Radio-humeral Bursitis." *Arch. Surg* 1922, 4 420.
[3] Hughes E S R "Acute Deposition of Calcium near the Elbow" (including three case reports). *J Bone Joint Surg* 1950 32-B, 30

that short of excision of the shattered bone there is often permanent limitation of flexion-extension movement of the elbow !

FIG 808

FIG 809

FIG. 810

Radiographs appear to show a simple marginal fracture of the head of the radius with minimal displacement (though the keen observer will note a defect in the lateral part of the capitellum and wonder where the detached fragment may be). When the radial head was removed at operation it was obvious that the articular damage was much more severe than the radiographs suggested the detached fragment of capitellum was impacted between the pieces of the radial head (the capitellar fragment, which is largely cartilaginous, is white in contrast with the radial fragments) Operation by Mr Pearce, formerly Senior Orthopædic Registrar the London Hospital.

The fact that fracture of the head of the radius is sustained by impact of the lateral margin of the capitellum in valgus displacement of the joint is shown clearly in Figure 811—a lateral marginal sector was tilted outwards and the central part of the radial head was compressed The injury is exactly comparable to fractures of the tuberosity of the tibia where valgus strains of the knee joint drive the margin of the lateral femoral condyle into the tibia separating a marginal fragment and crushing the rest Similarly the capitellum of the humerus is driven into the radius so that it separates a marginal fragment and compresses the central part of the head

Importance of accurate reduction—Extension of the elbow joint is limited by the olecranon process locking in the olecranon fossa of the humerus If the lower fragment carrying the olecranon fossa is *tilted forwards* 30 degrees this locking occurs 30 degrees before the normal limit of extension movement is reached angulation of the bone from forward tilting of the lower fragment is then shown in a corresponding degree of permanent limitation of extension Similarly, uncorrected backward tilting of the lower fragment causes permanent limitation of flexion Moreover, if the fracture unites with lateral tilting of the lower fragment the forearm bones are carried laterally with it and there is a corresponding degree of cubitus valgus or cubitus varus These angulations are not corrected by later growth of the bone Lateral displacements without angulation grow straight in children (Figs 846-849) but limited flexion or extension movement and alteration in the carrying angle from angulation of the bone persist into adult life It is very important therefore in every supracondylar fracture to secure perfect realignment of the fragments

Manipulative reduction—The elbow is usually so swollen that it is impossible to feel the bony outlines and the perfect position that should be insisted upon cannot always be achieved by one manipulation Nevertheless if a surgeon is prepared to remanipulate and in difficult cases to manipulate several times these fractures can always be reduced without resort to skeletal traction [1 2] or operative reduction [3-4]—both of which may cause capsular contracture and permanent stiffness It is *essential to* use a general anæsthetic and to have a portable X ray machine in the fracture theatre so that any number of radiographically controlled manipulations can be performed This must be emphasised because my views on the management of supracondylar fractures have sometimes been misunderstood and have often been misrepresented When I speak of repeated manipulation by which to secure perfect position I mean repeated manœuvrings under X ray control *in the course of one manipulative procedure under one anæsthetic* I do not mean that the patient should be brought back to the theatre day after day for repeated anæsthetics and repeated manipulations That would be harmful and it might be dangerous—there is no need for it

Importance of traction—The most important part of the manipulation is traction applied in the long axis of the limb The elbow must never be forced into flexion unless traction is maintained throughout the movement because forcible flexion without traction fails to reduce the displacement and it may damage the vessels and nerves in front of the joint With one hand a grasp is taken of the patient s wrist and firm steady traction is maintained The thumb of the other hand is then placed over the front of the proximal fragment with the fingers behind the distal fragment While traction is continued the small fragment of the humerus is pulled forward and the elbow is flexed to about 30 degrees above the right angle (Figs 838 841)

Correction of lateral displacement—Lateral displacement is then corrected An assistant takes the limb by the wrist and holds the elbow flexed the surgeon applies direct lateral pressure with one hand over the side of the

Hey Groves E. W "Skeletal Traction in the Treatment of Fractures." *Brit J Surg.*, 1928 16, 155
Zeno, L. "Fracturas Supracondileas del Humero" *Rev Ortop traumat.*, 1934, 3, 432.
Fagge C. H. "Supracondylar Fracture of Humerus." *Brit med. J.*, 1936, 1 604
Girdlestone G R. "Avoidable Disasters." *Brit. med. J.*, 1936, 1 349

Fig 811

This fracture was obviously produced by impact of the lateral margin of the capitellum into the radial head separating a marginal fragment and crushing the medial part of the head.

Fig 812

Fig 813

This injury shows clearly how the head of the radius is fractured by impact against the capitellum by valgus displacement there was still subluxation of the joint when the patient came for treatment (Fig 812). The ulna was replaced and the fractured radial head excised by Mr Osmond-Clarke at the London Hospital (Fig 813)

Operative reduction of malunited supracondylar fracture—After more than three or four weeks the alternatives of treatment are immediate operative reduction or delayed osteotomy. Early open reduction with the extensive dissection needed often causes capsular contraction subperiosteal ossification and permanent stiffness. It is usually better to let the fracture unite in its displaced position and after several months to correct the backward or lateral tilting by supracondylar osteotomy which corrects the carrying angle or restores the flexion or extension movement that has been lost by backward or forward tilting of the lower fragment. Late osteotomy is an easy operation which does not involve extensive dissection round the joint and there is therefore no capsular contraction or periarticular ossification.

Osteotomy for cubitus valgus—If normal movement has been regained and the osteotomy is performed simply to correct cubitus valgus or varus the limb should be immobilised after operation in the extended position. In this position it is easy to estimate and control the carrying angle whereas if the elbow is flexed it is difficult to judge the degree of tilting of the small distal fragment and very difficult to control it especially since the fragment tends to fall back to its original position. Immobilisation of the joint in extension does not interfere in any way with the subsequent recovery of movement.

FIG 850

Reduction of supracondylar fracture with forward displacement. The elbow is immobilised in full extension. While the plaster is setting the limb is held with the correct carrying angle

Supracondylar fracture with forward displacement—If the fracture is of the less common type where the distal fragment is displaced forwards reduction presents no difficulty. It is necessary only to apply traction to the limb and extend it fully. In the extended position it is easy to judge the carrying angle and to apply lateral pressure to correct tilting of the lower fragment (Fig 850). A posterior plaster slab is applied and lightly bandaged in position. While the patient is up and about the limb hangs by the side but swelling of the fingers and hand should be avoided by elevating the limb on cushions when the patient sits or lies. The plaster is removed after three weeks. If reduction is perfect full movements are regained easily (Figs 851 854). It is a mistake to attempt reduction and immobilisation of this type of supracondylar fracture in the flexed position or indeed in any position other than that of full extension.

The impact in valgus is demonstrated even more clearly in Figures 812 813 where there was not only momentary displacement but persistent subluxation When the patient first came for treatment the forearm was still in valgus with the ulna displaced and tilted on the trochlea the radius being fractured by impact against the *capitellum*

The inference is obvious—every fracture of the radial head must be recognised as part of a widespread injury to the joint Sometimes there is such obvious comminution of the head of the radius that the decision cannot be in doubt the shattered bone must be removed But even when the radiographic evidence is less clear and there seems to be no more than depression or tilting of a marginal fragment, it is still often wise to remove the damaged bone (Figs 814 816)

Fig 814

Fig 815

Fig 816

All these fractures of the head of the radius should be treated by excision of the damaged bone—including the whole head of the radius and not just the marginal fragment

Earlier experiments in excising only the detached marginal fragment of the radial head failed The whole head should always be excised The injury does not consist solely in detachment of a marginal fragment it includes crushing of the rest of the radial head and unless all of it is removed the results are unsatisfactory

The ideal time for operation is within a few days or weeks of injury There is no liberty to adopt conservative treatment for several months in the belief that late excision can still be successful It is true that some improvement may be gained by late excision but the joint seldom regains normal function unless the operation is performed early

Technique of excision of the fractured head of the radius—There are important surgical details upon which the success depends There must of course be scrupulous aseptic technique A short incision should be centred accurately over the radial head care being taken not to extend the dissection so far down as to imperil the posterior interosseous nerve The common extensor tendon and underlying capsule should be divided without dissection into many planes so that the post-operative hæmatoma in which ossification may occur will be minimal When the radial head is exposed the periosteum should be divided close to the articular margin and reflected down the forearm being turned into full pronation and full

Fig 851

Flexion type of supracondylar fracture of the humerus with forward displacement.

Fig 852

Fig 853

The displacement remains uncontrolled if the elbow is immobilised in flexion or even at the right angle—or even below the right angle (Fig 852). The joint must be immobilised in the position of full extension (Fig 853)

Fig 854

If the fracture unites without displacement full movement of the joint is regained without difficulty despite immobilisation in extension

FIG 817

Comminuted fracture of the head of the radius exposed at operation. It is obvious that the fracture was produced by impact against the humerus, because the capitellum is fractured exactly opposite the depressed part of the radius. A cuff of periosteum is being turned down—an important measure to take before dividing the neck of the bone at the level of the upper border of the orbicular ligament

FIG 818

The head of the radius has been removed, and the articular cartilage of the radial notch of the ulna is now visible Note how the cuff of periosteum has completely covered the stump of the neck so that no raw bone is exposed; this prevents post-operative ossification of the hæmatoma.

INTERCONDYLAR FRACTURES OF HUMERUS

Intercondylar fractures of the humerus are sustained more often by adults than by children and they usually arise from direct falls on the point of the elbow. The wedge-shaped olecranon process is forced between the condyles which are separated from each other, slightly rotated and displaced forwards (Fig. 855). There is often comminution of the articular surface with displacement and impaction of small fragments.

Few injuries of the elbow are more difficult to treat. It may be impossible to secure perfect replacement by manipulation and traction. Operative reduction is difficult because it involves free dissection of the triceps and capsule of the joint and there is seldom natural stability of the fragments, so that reduction can be maintained only by many screws and plates. Adhesion of the triceps, contraction of capsule, avascular necrosis of loose fragments and the irritative reaction of metallic foreign bodies contribute to dense adhesion formation and permanent stiffness—despite the perfect anatomical reposition that may have been secured the final range of movement is usually less satisfactory than after manipulation even when manipulative reduction is less accurate.

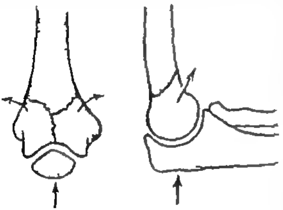

FIG. 855

Intercondylar T fractures are due to the olecranon being wedged between the condyles, which are rotated laterally and displaced forwards.

Manipulative reduction—The fracture is a flexion injury with forward displacement and it should not therefore be immobilised in the flexed position. Even the right-angled position is not entirely safe and if it is used special precautions must be taken to prevent persistent forward displacement of the fragments. The original Hugh Owen Thomas method was to manipulate the fracture and suspend the wrist from the neck by a collar-and-cuff sling with the elbow at the right angle, allowing gravity and the weight of the limb to maintain traction on the fragments.[1] This very simple procedure gives better results than operative reduction but the tendency to forward tilting of the lower fragments is shown by the frequency of permanent limitation of the last 30 or 40 degrees of extension.

It is usually better to immobilise the elbow in the extended position. Traction is applied to the fully extended joint and the condylar fragments are moulded into position by lateral compression. The limb may be supported in a Thomas arm splint with continuous skin traction for three weeks or still better immobilised in a plaster cast. The excellent result that may be secured even in difficult comminuted condylar fractures is shown in Figures 856-857.

Internal fixation of the condyles by one screw—There can be little doubt that the worst treatment of comminuted intercondylar fractures of the humerus is extensive operative reduction with internal fixation by triradiate plates and many screws. Such operations by stripping the blood supply of

[1] Eastwood, W. J. "T-shaped Fracture of the Humerus." J. Bone Joint Surg., 1937, 19, 364.

DISPLACEMENT OF THE EPIPHYSIS OF THE LATERAL CONDYLE

This injury occurs between the ages of five and fifteen years The separated fragment of bone is the whole lateral condyle of the humerus and includes the epiphysis of the capitellum, adjacent part of the trochlea and part of the metaphysis immediately above the capitellum to which the lateral ligament of the elbow and the common extensor origin of muscles are attached (Fig 803) The radiograph shows only the ossific nucleus of this large piece of incompletely ossified cartilage and this may account for the frequency with which the injury is overlooked or the displacement misinterpreted Nevertheless if the normal shape of the epiphysis of the capitellum is recalled two degrees of displacement can easily be recognised 1) The muscular aponeurosis overlying the fragment may be torn incompletely in which case the condyle is displaced laterally but not rotated and its fractured surface remains more or less in apposition with the fractured surface of its bed these fractures usually unite firmly by bone whether the slight lateral displacement is corrected or not 2) If the aponeurosis is ruptured completely the common extensor muscles avulse the fragment and rotate it from the joint so that its fractured surface is directed outwards with its articular surface inwards (Fig 804) There may be more than 90 degrees of rotational displacement and the fragment lies almost upside down Moreover it is rotated not only round a horizontal axis but also round a vertical axis so that the outer part of the epiphysis and the metaphyseal fragment lie on the inner side and the inner part of the epiphysis on the outer side (Fig 805) There is no contact between the fractured surfaces and unless the displacement is corrected bony union cannot possibly take place Repair is by fibrous tissue which is not strong enough to resist the continued thrust of the radius Displacement of the condylar fragment increases gradually cubitus valgus deformity develops and the carrying angle may become as much as 40 or 50 degrees (see page 135) Delayed ulnar palsy often arises after ten years at a time of strenuous occupational or recreational activity [1,2] The ulnar nerve is normally relaxed when the elbow is extended and relatively taut when the joint is flexed In the presence of marked cubitus valgus deformity the lengthened course of the nerve round the inner side of the joint makes it taut even in extension, and if the joint is flexed the nerve is overstretched The vigorous flexion movements of strenuous activity cause tension and friction neuritis with incomplete or even complete paralysis necessitating anterior transposition of the nerve These complications are to be avoided by accurate reduction at the time of the original bone injury

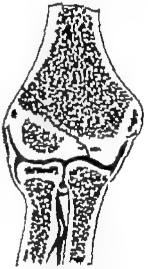

Fig 803

Line of fracture in separation of lateral condylar epiphysis.

Manipulative reduction—When there is lateral but no rotatory displacement complete reduction can usually be secured by manipulation The fragment should be pressed into its bed by direct lateral compression of the

Mouchet A "Paralysies tardives du Nerf Cubital [illegible] Fracture du Condyle externe" *J Chir Paris* 1914 12, 43
Davidson, A J & Horwitz M T "Tardy Ulnar Paralysis" (bibliography). *J Bone Joint Surg* 1935 17 844.

FRACTURE OF THE NECK OF THE HUMERUS

customary subdivision of fractures of the neck of the humerus int of the surgical neck and injuries of the anatomical neck does no ely represent the types it bears no relationship to the mechani m c and is of no value in determining treatment Three varieties c should be distinguished each with its characteristic mechanism

Fig 1

Fig 752

Fig 753

Three types of fracture of the neck of the humerus

Contusion crack fracture — Impacted adduction fracture — Impacted abduction fracture

Fig 754
Impacted adduction fracture.

Fig 755
Impacted abduction fracture.

l radiographic appearance and special method of treatment namely sion crack fractures adduction fractures abduction fractures (Figs) The patient s account of the injury is often unreliable but there e doubt that contusion crack fractures arise from direct blows over iter aspect of the shoulder, and the other two types from falls on the etched hand As the patient s hand strikes the ground with his trunk g to one side or the other the limb is forced either into abduction or tion and the corresponding fracture is produced In adults t

elbow between the surgeon s two hands Even if there is rotatory displacement manipulative reduction within a day or two of injury is by no means impossible [1 2] It is true that when the soft tissues have closed round the fragment like a buttonhole round a button manipulative reduction cannot be achieved but in almost one-third of the cases there is no such obstacle An assistant should hold the limb by the wrist with one hand with his other hand on the inner aspect of the elbow and gently open the joint on the outer side so that there is slight cubitus varus The surgeon then places both thumbs under the fragment and pushes it upwards and inwards tilting it into the joint The elbow is gradually flexed and the two condyles of the humerus are strongly compressed laterally so that the fragment is pressed firmly in its bed If reduction is perfect it is quite stable and if the elbow is then immobilised in flexion with a light plaster slab and a sling there will be no redisplacement (Figs 807 808)

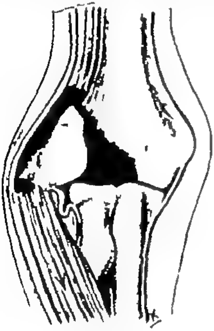

Fig 804
The epiphysis is rotated out of the joint by the pull of extensor muscles.

Operative reduction—If post-reduction radiographs do not show perfect reposition operative reduction must be undertaken without delay The fragment should be exposed with the minimum of dissection and care be taken not to detach the muscles and ligaments because they carry the blood supply and division of these tissues may cause necrosis of bone and stiffness of the joint Blood clot bone spicules and capsular tissue which may be filling the bed of the bone are removed The muscles arising from the condyle are gripped with forceps and the fragment is pulled upwards and rotated into position There is no need for internal fixation by nails screws or pegs.[3-4] Sufficient muscle and aponeurosis usually remain attached to both fragments to allow sound fixation by simple catgut suture and soft-tissue repair (Figs 805-806) and even if the tissues have been stripped from the proximal fragment it is still an easy matter to pass a catgut suture through a drill hole in the bone

Treatment of old un-united fractures of the lateral condyle [5]—Although the difficulties of operative reduction are very much greater after the first few weeks it may be possible to reduce the dislocated fragment even a year or two after injury This should always be preferred to excision of the fragment [6-] which does little or nothing to improve the range of movement or stability of the joint The fractured surfaces are cleared and freshened and the fragment is fixed by catgut sutures through drill holes If further fixation seems necessary a bone graft in the form of a peg should be driven through the fragment into the shaft of the humerus

Ogilvie W H (Section of Orthopaedics) "Fracture of Capitellum," *Proc Roy Soc Med* 19?? 23, 31
Wilson, P D "Fracture of Lateral Condyle of Humerus," *J Bone Joint Surg* 1936 18, 31?
Murphy J B "Fixation Lower Epiphysial Humerus by Nail," *Surg Cl* ..., 1916, 5, 277
Speed J ... and Macey H B "Fracture Humeral Condyles Children," *J Bone Joint Surg.*, 1933 15, 903
Moorhead, J L "Old Untreated Fracture External Condyle Humerus," *Surg Cl Chicago*, 1919 3, 9?
Pelle A "Ablation d Condyle Externe" *Z Orthopäd* 19??, 19, 4?
Reber H L et Guerin R "Fracture du Condyle Extirpation," *Arch franco-belg Chir* 1930, 32, 6?

to use strips of fascia cut from the thigh but this is really an unnecessary complication—catgut sutures are quite enough. The joint should be immobilised in a position short of full extension for about two weeks and active exercises are then practised (Figs 830 833)[1]

For many years it was taught by Albee that the triceps could not act efficiently without the leverage of the olecranon and the operation of excision of the olecranon has been criticised for this reason[2] Experience shows that this criticism is groundless. Normal power of extension against resistance is regained provided only that the triceps is securely stitched to the ulna. There is however one contraindication to excision of the olecranon namely fracture of the olecranon with forward dislocation of the joint (page 551). If such an injury is treated by excision of the large olecranon fragment the joint is liable to redislocate forwards

FIG 834

FIG 835

In each elbow joint of this patient there is a large fragment of bone lying above the olecranon. These are not fractures—the condition is sometimes described as patella cubiti. The ossicles are developed in the triceps tendon from secondary centres of ossification. The distinction from fracture can be made by the completeness of the shape of the olecranon in each joint, and the smoothness of the surfaces between the olecranon and the ossicle

Patella cubiti—Occasionally the secondary centre of ossification for the olecranon does not fuse to the upper end of the ulna but remains as a separate ossicle. When an elbow is injured this condition may be mistaken for a fracture of the olecranon. The distinguishing points are 1) the shape of the olecranon is complete 2) the separation is minimal 3) the adjacent bone surfaces are smooth 4) the condition is bilateral (Figs 834 835)

[1] Rombold, C. "Operation for Suture of Fracture of Olecranon." *J. Bone Joint Surg.*, 1934, 16, 94
[2] Hey Groves, E. W. "Fracture of the Olecranon." *Brit. med. J.*, 1939, 1, 496.

SUPRACONDYLAR FRACTURE OF THE HUMERUS

Supracondylar fracture of the humerus is one of the commonest elbow injuries in children and adolescents The line of fracture is usually oblique from the front of the bone upwards and backwards the small distal fragment being displaced backwards After traction has been applied the displacement can be corrected by flexing the elbow and, by reason of the obliquity of the fracture line reduction is stable in this position

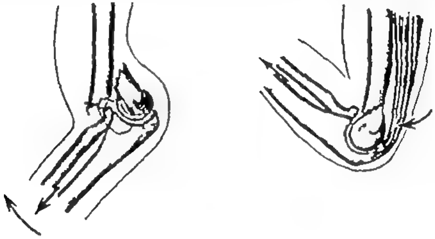

Fig 836

In a supracondylar fracture the small fragment is usually displaced backwards; after traction this is corrected by flexing the joint.

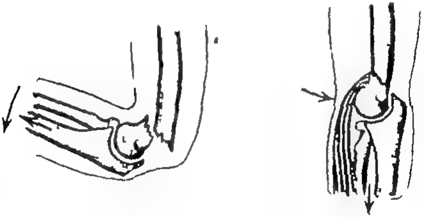

Fig 837

Occasionally there is forward displacement of the lower fragment; after traction the joint must be extended.

Less commonly a supracondylar fracture is oblique in the opposite direction the distal fragment is then displaced forwards and its displacement is increased by flexing the elbow It is clearly wrong to treat every supracondylar fracture in the flexed position—this is the correct position for the usual fracture but the opposite type of fracture must be immobilised *in the opposite position*

FIG 756

FIG 757

Adduction fracture of neck of humerus in a child before and after manipulative reduction and immobilisation in an abduction frame.

FIG. 758

FIG 759

Adduction fracture of the neck of the humerus in which closed reduction failed be
biceps tendon was interposed. At open operation, by Mr Laurence at the Robert Jo
Agnes Hunt Orthopædic Hospital, the opportunity was taken to fix the fragments with

the screw head as advocated by Vere Hodge, and even if the special Bosworth screw is used with a broad head and wide screw threads It is doubtful whether any form of internal fixation alone will immobilise a joint which has such little inherent stability as the dislocated acromio-clavicular joint

FIG 744

Recent dislocation of acromio-clavicular joint immobilised by coraco-clavicular screwing The technique is not very reliable though it may sometimes be a useful addition to external support by strapping

Operative treatment of old unreduced acromio-clavicular dislocations—In late unreduced acromio clavicular dislocations operative treatment is by no means essential Excellent function is often regained despite abnormal mobility of the clavicle The most strenuous work even heavy dock labouring has been undertaken by many patients with a persistently dislocated outer end of the clavicle Sometimes however there is continued disability and operations have been devised to reconstruct the damaged ligaments by two strips of fascia lata one encircling the coracoid and clavicle to represent the coraco-clavicular ligaments and the other passing from above the outer end of the clavicle to the under surface of the acromion fixed in drill holes in the bone [1-4] These operations are unreliable and it is better to excise the outer end of the clavicle

Acromio-clavicular arthroplasty [5-6]—Excision of the outer end of the clavicle which is so successful in relieving the pain of acromio-clavicular arthritis is also advisable when there is pain from acromio-clavicular dislocation At least half an inch of the bone should be excised The soft tissues are then firmly sutured but no attempt is made to repair the ligaments In recent years it has been shown that good function is possible even when the whole clavicle has been excised and certainly there need be no fear in

Watkins J T "Operation for Acromio-clavicular Luxations" *J Bone Joint Surg* 1925 7 790.
Bunnell S "Fascial Graft for Dislocation of Acromio-clavicular Joint." *Surg Gynec Obstet.*, 1928 46, 563.
Schneider C C "Acromio-clavicular Dislocation." *J Bone Joint Surg* 1933, 15, 957
Meyerding H W "Treatment of Acromio-clavicular Dislocation." *Surg Clin N Amer.*, 1937 17 1199.
Gurd, F B "Treatment of Complete Dislocation of Outer End of Clavicle" *Ann Surg.*, 1941 113, 1094.
Mumford, E. B. "Acromio-clavicular Dislocation." *J Bone Joint Surg* 1941 23, 799

incidence of the three groups of fracture is almost the same, abduction fractures being only slightly more common than the other two types. In children, on the other hand, only one fracture is at all common—the adduction fracture.

Contusion crack fracture of neck of humerus.—This injury is a contusion fracture of the great tuberosity together with a crack across the neck of the bone. The crack is almost invariably a subperiosteal injury without displacement. It is therefore unnecessary to immobilise the limb. Adhesions should be minimised by early exercise without passive stretching, and recovery is usually complete within two or three months.

Adduction fracture of neck of humerus.—The fracture lies high in the neck of the humerus with outward angulation of the fragments and impaction on the inner side. The shaft is adducted in relation to the head (Fig. 754). If displacement is not corrected and the fragments unite in this position abduction movement will be limited permanently by a degree corresponding to the degree of angulation. In elderly patients this is unimportant for the angulation is seldom more than 30 degrees; the impaction should not be broken down. The limb may be supported in a sling for two or three weeks and recovery is rapid.

In younger patients displacement should be corrected by traction and abduction of the limb, the shoulder being immobilised in an abduction frame or plaster spica for about four weeks (Figs. 756-757). Sometimes there is interposition of soft tissues between the fragments, such as a fold of capsule or the tendon of biceps, which makes it impossible to reduce the displacement by traction alone. The bone should then be exposed through the delto-pectoral groove; after interposing tissue has been removed the fragments are replaced in alignment, and it may be wise to take the opportunity of securing internal suture by a single transfixion screw (Figs. 758, 759), special care being taken to avoid damage to the epiphyseal plate.

The fracture may lie so close to the epiphyseal line as to amount to a *displacement of the upper humeral epiphysis*; even apart from operative intervention it is possible for the inner part of the epiphysis to be crushed by the adduction impaction, thus causing late recurrence of deformity from arrested growth of this part of the epiphysis.[1]

Abduction fracture of the neck of humerus.—There is inward angulation; the shaft is abducted in relation to the head, and there is impaction of the fragments on the outer side—always with a fracture of the great tuberosity which is pinched off between the outer margin of the shaft and the outer part of the head (Fig. 755). Manipulation is unnecessary. The limb should be supported in a sling; movements of the finger, wrist and elbow joints are begun at once, and shoulder movements are practised after two or three weeks. This fracture should not be immobilised in an abduction frame because such treatment only increases the tendency to abduction displacement.

Abduction fracture-dislocation of humerus.—Occasionally, abduction displacement of the shaft in relation to the head is much more severe and the injury amounts to a fracture-dislocation. The shaft is impacted into the head with as much as 80 or 90 degrees of abduction angulation. The tuberosity is sheared off and displaced by the shaft until it lies above the

[1] Aitken, A. P. "End Results of Fractures Proximal Humeral Epiphysis." *J. Bone Joint S.* ...

SUPRACONDYLAR FRACTURE OF THE HUMERUS

Supracondylar fracture of the humerus is one of the commonest elbow injuries in children and adolescents. The line of fracture is usually oblique from the front of the bone upwards and backwards, the small distal fragment being displaced backwards. After traction has been applied the displacement can be corrected by flexing the elbow and, by reason of the obliquity of the fracture line, reduction is stable in this position.

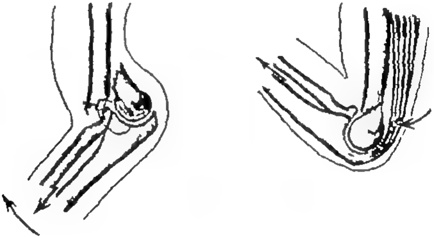

FIG. 836

In a supracondylar fracture the small fragment is usually displaced backwards; after traction this is corrected by flexing the joint.

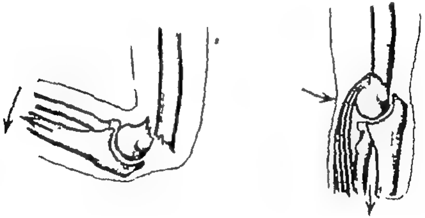

FIG. 837

Occasionally there is forward displacement of the lower fragment; after traction the joint must be extended.

Less commonly, a supracondylar fracture is oblique in the opposite direction; the distal fragment is then displaced forwards and its displacement is increased by flexing the elbow. It is clearly wrong to treat every supracondylar fracture in the flexed position—this is the correct position for the usual fracture, but the opposite type of fracture must be immobilised in the opposite position.

articular surface The head of the humerus being impacted into the shaft moves with it and when the limb is brought down to the side the head is pulled away from the glenoid fossa and a type of fracture-dislocation is produced (Figs 760 761) The joint is completely disorganised there is gross distortion of the articular surface and displacement of the tuberosity interferes with the function of supraspinatus so that the ultimate range of active movement is even less than the range of passive movement Treatment is difficult *It is impossible to alter the position by manipulation* Operative reduction is a formidable procedure and if the capsular attachments to bone are dissected too freely the blood supply to the head which is impaired already may be reduced still further so that avascular necrosis supervenes

Conservative treatment—In elderly patients operative treatment is seldom advisable The shoulder should be supported in a position of 30 degrees abduction by a large axillary pad of wool. Movement of the distal joints should be preserved by immediate active exercise and shoulder movements may be encouraged after two or three weeks The stiffness of the shoulder *is partly compensated by scapular movement and a more useful limb will be* secured than might be expected. The limb should not be supported on a frame in right-angled abduction if this is done it may prove impossible to bring the arm down to the side and the resulting abduction deformity cannot be concealed (Figs 762 763)

Operative reduction—In younger patients operative reduction should be attempted Through a short capsular incision the head of the humerus is *levered off the neck and the tuberosity is replaced* Stability of the fragments may be augmented by fixing the long tendon of the biceps through a drill hole in the head of the humerus exactly as in Nicola's operation for recurrent dislocation

Arthrodesis of shoulder—If avascular necrosis supervenes and the joint does not undergo ankylosis sufficiently firm to be painless arthrodesis is advisable Articular cartilage is removed from the joint surfaces and a tibial bone graft is driven through the neck of the humerus into the glenoid. Alternatively combined intra and extra articular arthrodesis may be performed by burying the rawed acromion process in the outer part of the head and neck of the humerus [1 2] The humerus should be fixed in slight forward flexion slight external rotation and with an angle of about 50 degrees of abduction between the humerus and scapula Care must be taken *not to fix the arm in such wide abduction that the limb cannot be brought down* to the side

Unimpacted abduction fracture of neck of humerus—Occasionally in *abduction fractures the shaft is not impacted into the head but is* displaced below it Unlike every other fracture of the neck of the humerus there is no fixation between the fragments The loose head is therefore rotated laterally and abducted by the unopposed pull of muscles *inserted* into the tuberosity The shaft is pulled inwards and upwards by the pectoralis major biceps and coraco-brachialis This fracture is rare and accounts for less than 2 per cent of shoulder joint injuries

Manipulative reduction—The fragments of the humerus should be brought

1 Watson-Jones, R "Extra-articular Arthrodesis of Shoulder" *J Bone Joint Surg*, 1933, 15, 862.
2 Curtis F E, and Branch, H E. "Extra-articular Arthrodesis of Shoulder" *J Bone Joint Surg* 1937 19, 411.

the screw head as advocated by Vere Hodge and even if the special Bosworth screw is used with a broad head and wide screw threads It is doubtful whether any form of internal fixation alone will immobilise a joint which has such little inherent stability as the dislocated acromio clavicular joint

FIG 744

Recent dislocation of acromio-clavicular joint immobilised by coraco-clavicular screwing. The technique is not very reliable though it may sometimes be a useful addition to external support by strapping

Operative treatment of old unreduced acromio-clavicular dislocations—In late unreduced acromio-clavicular dislocations operative treatment is by no means essential Excellent function is often regained despite abnormal mobility of the clavicle The most strenuous work, even heavy dock labouring has been undertaken by many patients with a persistently dislocated outer end of the clavicle Sometimes however there is continued disability and operations have been devised to reconstruct the damaged ligaments by two strips of fascia lata one encircling the coracoid and clavicle to represent the coraco-clavicular ligaments and the other passing from above the outer end of the clavicle to the under surface of the acromion fixed in drill holes i the bone [1-4] These operations are unreliable and it is better to excise th outer end of the clavicle

Acromio-clavicular arthroplasty[5-6]—Excision of the outer end of th clavicle which is so successful in relieving the pain of acromio-clavicula arthritis is also advisable when there is pain from acromio-clavicula dislocation At least half an inch of the bone should be excised The sof tissues are then firmly sutured but no attempt is made to repair the ligament In recent years it has been shown that good function is possible even whe the whole clavicle has been excised and certainly there need be no fear i

Watkins J T "Operation for Acromio-clavicular Luxations" *J Bone Joint Surg.*, 1925 7 790
Bunnell, S "Fascial Graft for Dislocation of Acromio-clavicular Joint" *Surg Gynec Obstet* 1928 46, 56
Schneider C C "Acromio-clavicular Dislocation." *J Bone Joint Surg.*, 1933, 15, 957
Meyerding, H W "Treatment of Acromio-clavicular Dislocation." *Surg Clin N Amer.*, 1937 17 1199
Gurd, F B. "Treatment of Complete Dislocation of Outer End of Clavicle" *Ann Surg.*, 1941 113, 1094
Mumford, E. B. Acromio-clavicular Dislocation." *J Bone Joint Surg.*, 1941 23 799

Fig 700

Fig 761

Impacted abduction fracture-di location of the humerus before and after operative reduction The inset to Figure 700 shows the mechanism of displacement by which the tuberosity i shorn off and the humeral head impaled by the shaft in such abduction that when the limb comes down to the side it is di located from the glenoid. In this case additional stability of the small fragment of the head was gained by passing the tendon of the biceps through it (Nicola s procedure as formerly used for recurrent dislocation of the shoulder)

Fig 6_

Fig 703

It is unwise to treat abduction fractures in the abducted position the fracture unites with abduction deformity the inner margin of the distal fragment locks against the margin of the glenoid, and the arm cannot be brought down to the side Thi patient ha union of the fracture with about 0 degrees of di placement; she could not walk in a crow l An osteotomy wa performed to bring the limb to the side.

excising up to one inch of the outer end. This is much better than tryi achieve arthrodesis of the joint which nearly always fails and may (permanent limitation of abduction movement when it succeeds

FRACTURE OF THE SCAPULA

Fracture of the body of the scapula is usually caused by a direct cru injury and it is sometimes associated with fractures of the ribs The bo often comminuted but the fragments are so completely surrounded by mu and fascia that displacement is unimportant Firm strapping relieves discomfort

Fracture of the neck of the scapula—A fall on the side of the should on the outstretched hand may cause fracture of the neck of the sca The fracture extends from below the glenoid fossa to the base of the cor process The glenoid fragment is sometimes displaced downwards inwards and impacted into the main scapular fragment but the displace is seldom sufficient to cause disability and attempts to reduce it need n made The limb should be supported in a sling active exercises of shoulder being encouraged within two or three weeks

Fracture of the coracoid process—When there is dislocation of acromio clavicular joint the conoid and trapezoid ligaments sometimes out a fragment of bone from the coracoid which is displaced upwards the clavicle The coracoid process may also be fractured near its bas muscular violence the bone is pulled down to the front of the shou by traction of the muscles that arise from it—the short head of biceps the coraco-brachialis This injury may also complicate dislocations of shoulder [1] but there is no need to replace the avulsed fragment by operat indeed one of the operations recommended for recurrent dislocation i divide the coracoid process by osteotomy and allow it to slide down to front of the joint thereby increasing stability and preventing redislocat

FRACTURE OF THE GREAT TUBEROSITY OF THE HUMERUS

There are two varieties of fracture of the great tuberosity of the humerus contusion fractures and avulsion fractures (Figs 745-747) In contusion fractures the separated fragment of bone is large and often comminuted but serious displacement is unusual The injury is the result of a direct blow a fall on the side of the shoulder or impact of the tuberosity against the margin of the glenoid fossa in dislocation of the joint In avulsion fractures the separated fragment is small and involves only that part of the tuberosity into which the supraspinatus tendon is inserted Occasionally the fragment is completely avulsed and retracted to a position above the articular surface of the humerus Like the contusion fracture, this type may occur as an isolated injury or be a complication of dislocation of the shoulder joint

Radiographic examination of the tuberosities of the humerus [2]—Avulsion of the supraspinatus tendon is the most common source of chip fractures

[1] Watson-Jones, R. *Proc Roy Soc Med* 1936 29 1060 (Section of Orthopaedics.)
[2] Blackett, C W and Healy T R Roentgen Studies of Shoulder *Amer J Roentgen* 193 37 760.

into contact by adducting the shaft across the chest and pushing the upper end outwards by a hand in the axilla until the fractured surfaces engage[1] The arm is then brought back to the side and the limb is immobilised for three weeks by a collar and cuff sling axillary pad and bandage It is not immobilised on an abduction frame Movement of the distal joints is begun at once and movements of the shoulder after three weeks (Figs. 764 765)

The dangers of an abduction frame—Many surgeons believing that since the head of the humerus is abducted and externally rotated the shaft must be placed in a similar position, have treated this fracture in an abduction frame, but such treatment is not only uncomfortable—it may be dangerous. The fracture is produced by abduction force and if the limb is immobilised

Fig 764

Fig 765

Unimpacted abduction fracture of the neck of the humerus before and after manipulative reduction by adducting the shaft across the chest and pushing the upper end outwards. The limb was immobilised by the side. Although the position is not quite perfect, so that the last few degrees of abduction are limited, the resulting disability is quite unimportant as compared with that shown in Figures 762 763 where the limb cannot be brought to the side.

in abduction the shaft of the humerus may again displace below the head and unite in this position so that the patient is unable to bring the limb down to the side (Fig 763) Abduction fractures should be treated with the limb by the side of the trunk. Even when there is complete disengagement of the fragments a sufficiently good position can usually be secured by manipulation.

Treatment by intramedullary nailing—Alternatively the fragments may be placed in contact with each other after exposure through a short incision and be fixed with an intramedullary nail A short nail is introduced through an oblique canal in the cortex of the humerus at the site of insertion of the deltoid where the shaft of the bone is subcutaneous The nail is driven upwards into the head of the humerus under visual control through the delto-pectoral incision by which the fracture has been exposed[2]

[1] Franken C Manipulative Reduction Fractures of the Surgical Neck of the Humerus." *Lancet*, 1933, 2, 735.
[2] Palmer I *J Bone Joint Surg* 1950 32-B, 726.

Fig. 745

Fig. 746

Fig. 747

Types of fracture of the tuberosity of the humerus

Fig. 745—Contusion fracture of the great tuberosity of the humerus. Fig. 746—Avulsion fracture of the tuberosity without displacement. Fig. 747—Avulsion fracture of the tuberosity with displacement.

Fig. 748

Contusion fracture of great tuberosity

Fig. 749

Avulsion fracture of great tuberosity without displacement.

Fig. 750

Avulsion fracture with the fragment retracted above the humerus.

FIG 773

FIG. 774

FIG 775

Dislocation of the shoulder with fracture of the great tuberosity (Fig 773) After reduction of the dislocation, radiographs show that the tuberosity has been displaced by the supraspinatus so that it lies above the head of the humerus (Fig 774). The limb must be abducted and externally rotated and immobilised in a plaster spica (Fig. 775).

FIG. [illegible]6

FIG. [illegible]

An abduction frame is needed when a dislocation of the shoulder is complicated by fracture of the great tuberosity with retraction of the fragment or by avulsion of the supraspinatus tendon (Fig. [illegible]6). The frame must not be allowed to slide down the trunk and many bandages should be used to support it over both shoulders (Fig. [illegible]). Unless such care is taken there is danger of redislocation.

Fig. 858

is patient fell the point of e elbow On st inspection of e radiographs ere appears to no bone injury r displacement

Fig 858

Fig 859

omparison with he normal elbow Fig 860 print eversed for easier omparison) shows hat the lower umeral epiphysis s tilted and displaced forwards.

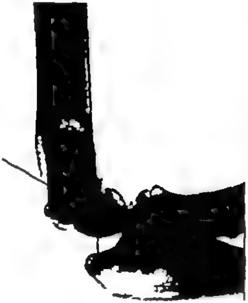

Fig 859

Fig 860

Fig. 861

When the elbow s fully extended, the displacement corrected The joint must be mmobilised in plaster in the position of full extension.

elbow is extended and the epicondyle may be felt to slip out of the joint. The manœuvre may be aided by stimulating the flexor muscles with a faradic coil [1]

Operative reduction—A short incision is made on the inner side of the joint. As soon as the deep fascia is divided it is seen that the inner aspect of the humerus below the raw bed of the epicondyle is uncovered and that the muscles and fascia which normally cover it are turned into the inner side of the joint (Fig 874). It is an easy matter to hook the muscles out and with them the epicondyle. The bone is stitched to its normal position

Fig 875

Fig 876

What is the youngest age at which inclusion of the medial epicondyle of the humerus within the elbow joint has been recorded? The centre of ossification is supposed to appear at seven years, and yet this child was aged only six, and there was no doubt clinically, radiographically or at operation that the epiphysis of the epicondyle was in the medial side of the joint (Fig 875—compare the normal elbow shown in Fig 876). The fact is of course that it is the common flexor origin that is trapped whether or not the epiphysis has begun to ossify

by means of one or two catgut sutures through adjacent soft tissues. It is unnecessary to nail the fragment to the shaft. It is probably advisable to take the opportunity of transposing the ulnar nerve to the front of the joint. There has been some disagreement on this. Many surgeons have pointed out that the ulnar paralysis usually recovers even without such transposition but if an open operation is needed to withdraw the fragment of bone from the joint it seems a pity to neglect the opportunity of relieving the nerve from the effects of thickening and irregularity of the postcondylar groove which are almost inevitable

[1] Fairbank, H. A. T., & Buxton, St. J. D. "Displacement of Epicondyle into Elbow Joint." *Lancet* 1934 2, 218.

INJURIES AT THE ELBOW

EPIPHYSEAL INJURIES AT THE ELBOW

The epiphysis at the lower end of the humerus includes three main centres of ossification one appearing during the second year for the capitellum and two appearing several years later a double centre for the trochlea and one for the medial epicondyle There is occasionally a small separate centre for the lateral epicondyle (Fig 862) As a rule the medial epicondyle is soon separated from the rest of the epiphysis by an extension of the shaft between it and the trochlea The capitellum and trochlea fuse to each other shortly before puberty and to the shaft a year or two after puberty The medial epicondyle fuses one year later

A fall on the point of the flexed elbow may displace the whole of this epiphysis forward the separated fragment including the ossific centres of the capitellum the trochlea and sometimes the medial epicondyle More often, and as the result of a fall on the outstretched hand there is a fracture through the cartilage and one of the centres is pulled from the rest by muscle traction When the joint is forced into valgus the epiphysis of the medial epicondyle may be avulsed by the common flexor group of muscles which are attached to it and similarly, when the joint is forced into varus the capitellum may be avulsed by the common extensor origin The lateral epicondyle has such a small and inconstant ossific centre that it is seldom avulsed independently of the rest of the condyle

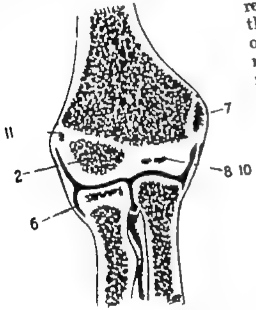

Fig 862

The epiphyses at the elbow joint, the figures indicating the year of appearance of each centre of ossification.

Displacements of the epiphyses at the elbow joint show the feature that characterises nearly all epiphyseal displacements The line of fracture does not coincide exactly with the epiphyseal line but lies close to it on the diaphyseal side The displaced fragment includes the epiphysis the epiphyseal line and a triangular fragment from the diaphysis The triangular fragment is always separated from that margin of the diaphysis over which the epiphysis is displaced

Summary of epiphyseal injuries at the elbow—Thus epiphyseal injuries at the elbow include 1) displacement of the upper radial epiphysis 2) displacement of the olecranon epiphysis 3) displacement forwards of the whole of the lower humeral epiphysis and 4) displacement of parts of the lower humeral epiphysis to be discussed in succeeding pages These include i) displacement of the lateral condyle of the humerus which may be rotated out of the joint and cause serious disability unless recognised and corrected ii) separation of the epiphysis of the lateral epicondyle which is seldom important iii) separation of the epiphysis of the medial epicondyle which is common and very important often with inclusion of the fragment within the joint

DISLOCATION OF THE ELBOW JOINT

Although supracondylar fractures of the humerus and some other injuries of the elbow occur with particular frequency in patients of certain age groups dislocations of this joint may be sustained at any age (Fig 877) The forearm bones are usually displaced backwards or backwards and outwards or backwards and inwards and the brachialis anticus is torn from the coronoid process Such avulsion encourages the formation of a hæmatoma beneath the displaced periosteum In this subperiosteal hæmatoma bone is laid down and continues to be laid down until the periosteum is replaced in normal contact with bone by reduction of the displacement Abnormal ossification is of course increased if the hæmatoma is scattered by repeated passive stretching or forcible movement Thus the first principle of treatment of dislocations of the elbow joint is prompt reduction of the displacement with immobilisation of the joint in a flexed position for three weeks (Fig 878) and recovery of movement by active exercise alone without passive stretching or repeated forcible movement

Fig 877
Backward dislocation of the elbow joint.

The dangers of delayed reduction and of passive stretching in the endeavour to mobilise a stiff elbow were discussed in the first volume of this book where it was also pointed out that secondary nerve lesions may be produced by forcible mobilisation The vascular complications of dislocation of the elbow including primary injuries of the brachial artery [1,2] *and secondary vascular obstructions* from flexing the joint too much or from applying tight encircling dressings causing Volkmann's ischæmic contracture were also discussed

Fig 878
After reduction of the dislocation the elbow is immobilised by a simple collar and-cuff sling

Clinical features—The deformity of backward dislocation of the elbow joint is to be distinguished from that of backwardly displaced supracondylar fracture by *the relative immobility of the* dislocated bones and by the abnormal relationship of the olecranon to the epicondyles The diagnosis must be confirmed by radiographic examination

[1] Marnham R "Dislocation of Elbow with Rupture of Brachial Artery" *Brit J Surg* 1934 22, 181
[2] Henderson R and Robertson I M "Open Dislocation of the Elbow with Rupture of the Brachial Artery" *J Bone Joint Surg* 1952, 34-B, 636.

the partly detached fragments and causing adhesion of muscle to bone, cause serious joint stiffness But on the other hand Mervyn Evans[1] recently described a successful series of cases in which through a limited

FIG 836

FIG 837

Intercondylar fracture before and after manipulation reduction and immobilisation in full extension of the elbow The patient regained almost normal function with extension movement to 180 degrees and flexion to 43 degrees.

exposure sometimes on the lateral side of the joint but more often on the medial side he fixed the condylar fragments with a single screw placed transversely so that in effect a comminuted fracture of the lower end of the humerus was converted into a simple supracondylar fracture which

[1] Evans E. Mervyn. *J Bone Joint Surg.*, 1953, 35-B, 140.

because otherwise it is impossible to know whether or not the dislocation is accompanied by fractures of the radial head, the epicondyles, or the condyles of the humerus

Manipulative reduction—If there is no associated fracture it is easy to reduce a dislocated elbow joint There need be no violent traction, and certainly there should be no full extension of the joint as a preliminary to reduction by flexion Still less is it wise to hyperextend the joint—this is a dangerous manœuvre Gentle traction should be applied to the forearm in the position in which it lies While traction is maintained the joint is flexed and if there is lateral displacement appropriate pressure is applied

After treatment—A simple collar and-cuff sling should be applied with the elbow comfortably flexed Radiographs must be taken to confirm the accuracy of reduction Reduction is usually stable but a posterior plaster slab may be applied to prevent redisplacement Shoulder and finger exercises are begun at once Movement of the elbow should not be instituted for three weeks and it is then restored by the patient s unaided activity There must be no massage and no passive or forcible movements Such treatment causes increased stiffness and may produce myositis ossificans a complication that should never be seen in dislocations of the elbow and occurs only if reduction is delayed or if passive stretching is practised

Treatment of old unreduced dislocations—Manipulative reduction may still be possible several weeks after injury Steady prolonged traction is necessary while the elbow is gradually flexed If reduction is successful the joint should be immobilised in flexion for three or four weeks Active movements are then permitted whether or not there is evidence of traumatic subperiosteal ossification Abnormal bone formation is promoted by passive stretching but not by active exercise and it consolidates just as rapidly when gentle exercise is permitted as when the joint is immobilised rigidly for many months Moreover a far better range of movement will be regained if active exercises are encouraged after three or four weeks

If manipulation fails the choices of treatment are open reduction sham reduction and arthroplasty An immediate open reduction may be permissible if there is no extensive ossification round the joint but it is unlikely that full movements will be regained [1, 2] The 'sham reduction ' of Hugh Owen Thomas was simply to flex the elbow above the right angle and hold it in this position by a collar-and-cuff sling for three weeks the patient then being encouraged to regain the best movement he could at the false joint This is usually the best treatment for a dislocation two or three months old already showing evidence of ossification round the joint—but even at this early date arthroplasty should be considered

Arthroplasty of the elbow for old unreduced dislocations—When a dislocated elbow joint has been unreduced for many months and there is painful stiffness arthroplasty is usually the best treatment The lower end of the humerus should be removed at the level of the epicondyles the olecranon process the coronoid and the head of the radius are also excised The forearm bones are brought forward into normal relationship with the humerus and the

Speed J S "Operation for Unreduced Posterior Dislocation of Elbow" *Sth med J*, Nashville 1925, 18, 193.
Vangorder G W "Old Posterior Dislocation of Elbow" *J Bone Joint Surg*, 1932, 14 127

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[1] Markham R Dislocation of Elbow with Rupture of Brachial Artery, *Brit J Surg.*, 1934 22, 181
[2] Henderson R and Robertson I M. Open Dislocation of the Elbow with Rupture of the Brachial Artery *J Bone Joint Surg* 1952, 34-B, 636.

FIG 865

Displacement of the epiphysis of the lateral condyle. The fragment is rotated so that its fractured surface is directed outwards. It is rotated through 180 degrees round a longitudinal axis. (The marks + indicate normally contiguous points.)

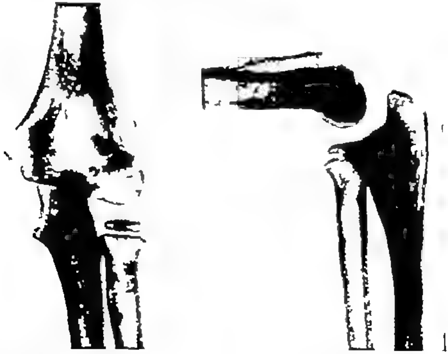

FIG 866

The same case as that of Figure 865 six months after operative reduction and catgut suture of the overlying soft tissues. It is only the unreduced fracture that fails to unite. After accurate manipulative or operative reduction, union is rapid and recovery is complete.

because otherwise it is impossible to know whether or not the dislocation is accompanied by fractures of the radial head the epicondyles or the condyles of the humerus

Manipulative reduction—If there is no associated fracture it is easy to reduce a dislocated elbow joint There need be no violent traction and certainly there should be no full extension of the joint as a preliminary to reduction by flexion Still less is it wise to hyperextend the joint—this is a dangerous manœuvre Gentle traction should be applied to the forearm in the position in which it lies While traction is maintained the joint is flexed and if there is lateral displacement appropriate pressure is applied

After-treatment—A simple collar and cuff sling should be applied with the elbow comfortably flexed *Radiographs must be taken to confirm the accuracy* of reduction Reduction is usually stable but a posterior plaster slab may be applied to prevent redisplacement Shoulder and finger exercises are begun at once *Movement of the elbow should not be instituted for three* weeks and it is then restored by the patient s unaided activity There must be no massage and no passive or forcible movements Such treatment causes increased stiffness and may produce myositis ossificans a complication that should never be seen in dislocations of the elbow, and occurs only if reduction is delayed or if passive stretching is practised

Treatment of old unreduced dislocations—Manipulative reduction may still be possible several weeks after injury Steady prolonged traction is necessary while the elbow is gradually flexed If reduction is successful the joint should be immobilised in flexion for three or four weeks Active movements are then permitted whether or not there is evidence of traumatic subperiosteal ossification Abnormal bone formation is promoted by passive stretching but not by active exercise and it consolidates just as rapidly when gentle exercise is permitted as when the joint is immobilised rigidly for many months. Moreover a far better range of movement will be regained if active exercises are encouraged after three or four weeks

If manipulation fails the choices of treatment are open reduction ' ~~sham-reduction~~ and arthroplasty An immediate open reduction may be permissible if there is no extensive ossification round the joint but it is unlikely that full movements will be regained [1 2] The sham reduction of Hugh Owen Thomas was simply to flex the elbow above the right angle and hold it in this position by a collar and-cuff sling for three weeks the patient then being encouraged to regain the best movement he could at the false joint This is usually the best treatment for a dislocation two or three months old already showing evidence of ossification round the joint—but even at this early date arthroplasty should be considered

Arthroplasty of the elbow for old unreduced dislocations—When a dislocated elbow joint has been unreduced for many months and there is painful stiffness arthroplasty is usually the best treatment The lower end of the humerus should be removed at the level of the epicondyles the olecranon process the coronoid and the head of the radius are also excised The forearm bones are brought forward into normal relationship with the humerus and the

Speed J [illegible] Operation for Unreduced Posterior Dislocation of Elbow Sth. med J., 3 [illegible] 192., 18, 193
Vangorder [illegible] W "Old Posterior Dislocation of Elbow" J Bone Joint Surg., 193., 14, 127

limb is immobilised by means of a plaster cast in the moderately flexed position for about three weeks before active exercises are begun. It is important to realise that brilliant as are the results of arthroplasty of the elbow in rheumatoid arthritis and old infective arthritis where fibrosis around the joint promotes stability, too free excision of bone in a recently injured elbow and too early mobilisation after excision may cause grave disability from the weakness of an almost flail limb. Arthrodesis would be better than this, especially for those who engage in heavy manual activity. Nevertheless, if there is discretion in the amount of bone removed and if active mobilisation of the false joint is deferred for several weeks, the results of arthroplasty can be excellent.

FIG. 879

Two months old dislocation of the elbow. Failure to reduce the dislocation and so to replace the periosteum has caused myositis ossificans. Manipulative or operative reduction is therefore contraindicated and arthroplasty may offer the best prospect.

Arthrodesis of the elbow for old unreduced dislocations.—My own preference in the treatment of old unreduced dislocations of the elbow joint is always for arthroplasty, which if done carefully and with suitable after treatment usually gives a joint with good movement and reasonable stability. But on the other hand a good argument can be made for arthrodesis in the case of men who must pursue arduous labour. Certainly an elbow which is fused soundly is painless and strong, and in certain circumstances it may be better. After refreshening the joint surfaces and putting them in apposition, cancellous chips of bone from the ilium should be packed into the gaps. The elbow should usually be fixed in a position 10 or 20 degrees below the right angle, care being taken to avoid fusion of the upper end of the radius so that full radio-ulnar movement of the forearm will be preserved. It is often wise to excise th[illegible] per end of the radius either at the time of the original arthrodesi[illegible] humero-ulnar joint or sometimes at a secondary operation some mont[illegible] r

for a year or two it is obvious that such avulsion must be unusual Two very rare cases of avulsion of the lateral epicondyle with inclusion of the fragment in the elbow joint are illustrated in Figures 869 870 It must be

Fig 869

Inclusion of external epicondyle epiphysis in elbow joint after reduction of a dislocation in a boy aged twelve.

Fig 870

Youth aged nineteen, who at the age of thirteen displaced the external epicondyle into the elbow without actually dislocating the joint.

understood that whereas avulsion of the epiphysis of the medial epicondyle often with inclusion within the joint is quite common corresponding injury to the lateral epicondyle is very rare indeed in fact I do not know of any reported cases other than these two

DISPLACEMENT OF THE EPIPHYSIS OF THE MEDIAL EPICONDYLE

Until the age of eighteen when the medial epicondyle fuses to the humerus the epiphyseal line is a potential source of weakness Avulsion of the epiphysis by traction of the common flexor muscles from valgus strain of the joint is one of the commonest injuries of the elbow joint in adolescents

Four clinical types—There are four degrees of displacement of the epiphyseal fragment of bone (Fig 871) 1) The least serious injury is slight separation of the epiphysis with minimal displacement 2) If the strain is more forcible the fragment is pulled down to the joint level and there is traumatic synovitis of the joint 3) If the valgus strain is still stronger the fragment is avulsed the joint is momentarily opened on the inner side and as the humerus and ulna snap together again the epiphysis is included within the joint on the inner side 4) If valgus strain continues the fourth degree of displacement arises avulsion of the epicondyle being associated with complete outward dislocation of the elbow unless such a dislocation is manipulated carefully the epiphysis may be included within the joint [1]

[1] Watson-Jones R. "Nerve Lesions in Injuries of the Elbow" *J Bone Joint Surg.*, 1930 12, 121

FRACTURE-DISLOCATIONS OF THE ELBOW

Dislocation of the elbow joint with fracture of the coronoid process—In many dislocations of the elbow joint the injury to the insertion of the brachialis anticus is shown by a chip fracture of the coronoid process Small fragments of bone may be retracted from the ulna This injury is of no significance and if the usual after treatment is carried out by immobilising the joint in flexion the fracture will unite and cause no disability When larger fragments of the coronoid are broken off the reduction may be less stable and to guard against the possibility of redisplacement a posterior plaster slab should be used as well as a collar and-cuff sling

FIG 880

Forward dislocation of the elbow with fracture of the olecranon process—an injury that is sometimes complicated by paralysis of the ulnar nerve.

FIG 881

Same case as that of Figure 882 after manipulative reduction of the dislocation and suture of the olecranon. Repair of the fracture is usually slow

Forward dislocation of the elbow joint with fracture of the olecranon [1 2]—The elbow is seldom dislocated forwards unless there is also a fracture of the olecranon This injury is usually caused by a fall on the back of the upper forearm which fractures the ulna and drives both forearm bones forward (Fig 880) the ulnar nerve may be damaged by traction over the lower end of the humerus This fracture-dislocation of the elbow should be treated in extension it is easily reduced by applying traction extending the joint and pressing backwards on the front of the upper forearm An anterior plaster slab is then applied If the olecranon fracture is not reduced perfectly operative reduction and suture of the fragment should be undertaken ten days later (Fig 881) After operation the joint may be

Cohn I "Forward Dislocation both Bones of Forearm at Elbow" *Surg Gyn Obstet.*, 1922, 35, 776.
Tees F J., and Mekim L. H "Anterior Dislocation of Elbow" (analysis of recorded cases of forward dislocation without fracture of olecranon). *Canad med Ass J.*, 1929 20, 36.

The degree of displacement of the internal epicondyle is an index to the degree of stretching of all structures on the inner side of the joint including the ulnar nerve With increasing displacement we find an increasing incidence of traumatic ulnar neuritis Complete outwar dislocations of the elbow and subluxations with inclusion of the epicondy are nearly always associated with complete or incomplete ulnar paraly Not only is the nerve stretched and bruised[1,2] but it may be kinked distorted one case has been reported where it was displaced into the elb joint with the bone fragment[3]

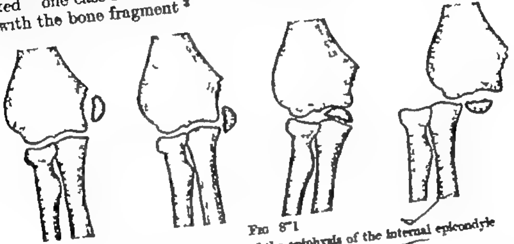

Fig 871

The four degrees of displacement of the epiphysis of the internal epicondyle

Treatment of displacement of the medial epicondyle—Operative treatment is unnecessary for the first two degrees of displacement of the medial epicondyle The bone is pulled from its bed and the fracture hæmatoma may be obliterated by adjacent soft tissues so that fibrous union develops Nevertheless the common flexor muscles gain a new attachment to the humerus through scar tissue which surrounds the bone fragment and encloses it like a sesamoid The elbow becomes just as strong as if bony union had been secured Indeed the most important part of the treatment of these cases is the treatment of the associated traumatic synovitis. The joint should be rested in a sling and movement must be regained slowly by active exercise It is often many months before full extension movement is regained and if forcible measures are adopted it may be limited permanently

Diagnosis of inclusion of epicondyle in joint—The clinical diagnosis is seldom difficult despite the marked swelling of the joint and the œdema and ecchymosis on the inner side When the elbow is compared with the normal joint of the opposite side it is usually obvious that the epicondyle has disappeared from its normal position If there is also a complaint of tingling or numbness in the ulnar distribution on the inner side of the fingers and hand the diagnosis is almost certain The radiographic evidence is equally obvious Every patient between the ages of seven and seventeen should have a separate centre of ossification in the position of the internal epicondyle If there is no ossicle in that position it should be searched for on the inner side of the joint it will be found overlapping the shadow of the trochlea,

[1] Walls H B Displacement of Epicondyle into Elbow Joint. Brit J Surg 1934 ?? 677
[2] Fairbank H A T Affections of the Epiphyses Proc Roy Soc Med 1934 ?? Sect Orth ?
[3] Cotton F J Elbow Dislocation and Ulnar Nerve Injury J Bone Joint Surg 1929 11 348

immobilised at the right angle. Union of the fracture is usually slow, and immobility should be maintained for about two months. Full movements may not be regained in less than twelve or eighteen months. Since the olecranon fracture is low and the fragment includes more than half the joint surface these difficulties of slowness of union and delay in the recovery of movement should not be solved by excision of the fragment and suture of the triceps. It is an unsuitable fracture of the olecranon for this treatment because there is a danger of recurrent forward dislocation.

Side-swipe fracture-dislocation of the elbow or "baby-car fracture"—Some years ago in earlier editions of this book I described a fracture-dislocation of the elbow with forward displacement of both forearm bones, fracture of the olecranon, fracture of the lower shaft of the humerus and fracture of the upper shaft of the ulna sustained by drivers of cars who while resting an arm with the elbow projecting through the window met oncoming cars too closely. *I thought that the injury* was the particular penalty of small 8-horse powered cars in which there was no room to move but which nevertheless gained popularity in Britain when petrol was rationed. Thus I described it as "the baby-car fracture." But the same fracture-dislocation soon occurred even in the roomy and luxurious cars of America. These drivers also indulged in putting their elbows out too far and they quickly found a better title—the side-swipe fracture.

FIG. 882

Side-swipe fracture-dislocation

"Don't put your elbow out so far
It may go home in another car."[1]

The combination of injuries is quite typical and it presents a serious problem of treatment (Fig. 882). There is a danger of trying to correct all the displacements at once and succeeding in correcting none. The important displacement on which the surgeon should focus his attention is the forward dislocation of both forearm bones at the elbow joint. The fractures of the shafts of the humerus, ulna and sometimes the radius can always be dealt with successfully by later operative reduction, but unless the forward dislocation of the forearm bones at the elbow joint is reduced promptly there will be permanent disability with no better end result than that of arthroplasty or arthrodesis of the joint. The upper end of the radius and ulna should be pushed back until the small curved articular surface at the front of the upper end of the ulna is in normal relation with the condyle of the humerus. Usually it is best to

[1] The Burma [illegible] ... [illegible], quoted from personal letter from Col. Milton S. Thompson, U.S. Army Orthopedic [illegible] ... Texas.

or between the trochlea and the ulna The fragment may be turned to one side or it may be upside down (Fig 872) Even when anteroposterior

Fig 872

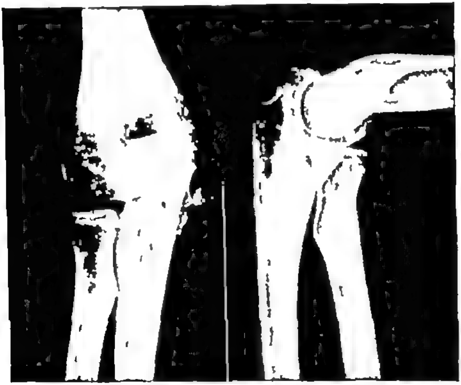

Fig 873

Inclusion of the internal epicondyle epiphysis within the elbow joint before and after manipulative reduction (by Mr Norman Roberts). There is only fibrous union, but movement and strength are normal.

radiographs are difficult to take without anæsthetising the patient the diagnosis can be made from lateral radiographs Patrick pointed out that if the epicondylar fragment can be seen at all in a lateral X ray it must be in the joint [1]

[1] Patrick J *J Bone Joint Surg.*, 1946 28, 143

immobilise the joint in the extended position If the dislocation is thus reduced and redisplacement is prevented the fracture of the olecranon can be dealt with some weeks later by reconstruction and internal fixation or by excision of the fragment and repair of the triceps There is still time even after that to realign the fragments of the fractured humerus and

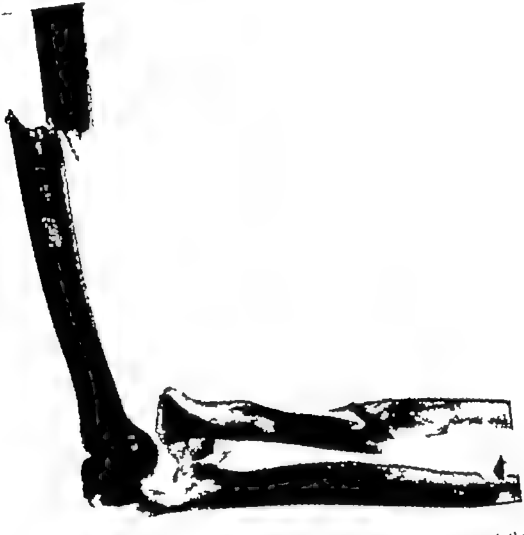

Fig 883

The typical combination of injuries produced by side-swipe when driving with the elbow out of the window and brushing too close to an oncoming car There is always a comminuted fracture of the olecranon, forward dislocation of both bones, fracture of the mid-shaft of the humerus and fracture of the shaft of the ulna; in this case there was also a fracture of the shaft of the radius.

the fractured forearm bones by open operation and internal fixation if there is residual displacement Actually by applying traction to the limb while the elbow joint is extended fully it may be possible to reduce all the displacements in one manipulation and provided that immobilisation in plaster is continued in the position of full extension of the elbow the only secondary operation needed is repair of the olecranon process and triceps insertion But sometimes a late arthroplasty of the elbow is inevitable despite every endeavour in early conservative treatment

The youngest patient in whom I have known this injury to occur was a child aged six years—an age at which the epiphysis seldom has a centre of ossification (Figs 875-876) There is of course no reason why the cartilaginous epiphysis of the medial epicondyle should not be avulsed and included within the elbow joint at a still earlier age but I have never heard of such a diagnosis being made or confirmed

Treatment of inclusion of epicondyle—It is essential to remove the fragment from the inner side of the joint or there will be serious and

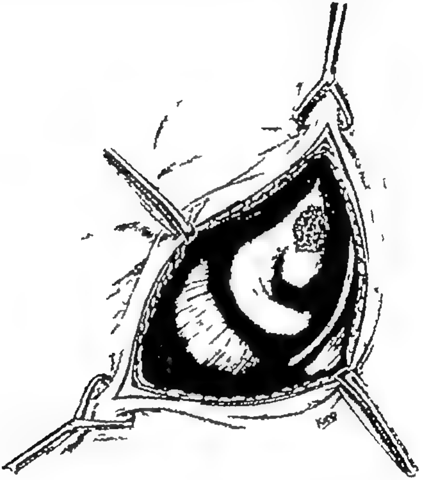

FIG. 874

Avulsion of the epiphysis of the internal epicondyle with inclusion in the elbow joint. The muscles are drawn into the joint with the fragment, and the ulnar nerve is bruised.

permanent limitation of movement and kinking of the ulnar nerve may interfere with recovery from the paralysis In recent injuries the fragment should be replaced as near to its normal position as possible by operative or manipulative reduction

Manipulative reduction—In recent cases it may be possible to extract the epiphysis from the joint by manipulation (Figs 872 873)[1] The valgus deformity is slightly increased by abducting the forearm so that the inner side of the joint is opened With the forearm fully supinated and the wrist and fingers extended so that there is tension on the flexor group of muscles, the

[1] Roberts, N. W. "Internal Epicondyle in Elbow—Four Cases Reduced by Manipulation." *Lancet* 1934 2, 78

Dislocation of the elbow joint with fracture of the head of the radius—Dislocation of the elbow may be accompanied by a marginal or comminuted fracture of the head of the radius One patient fell forward on both outstretched hands and sustained bilateral dislocation of the elbow joints with symmetrical marginal fractures of both heads of radius There is no difficulty in reducing the dislocation The fracture of the radius should then be treated as if it was an isolated injury If there is a displaced marginal fragment or comminution of the bone the whole head must be removed two or three weeks after reduction of the dislocation

A patient once showed me a scar on the inner side of his elbow and said that the head of his radius had been removed from it I pointed out that he meant the internal epicondyle but he insisted that it was the head of the radius When I still showed unbelief he delved into his pockets and

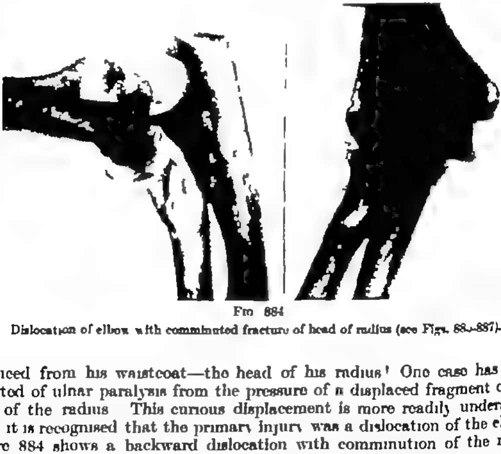

Fig 884

Dislocation of elbow with comminuted fracture of head of radius (see Figs. 885-887).

produced from his waistcoat—the head of his radius! One case has been reported of ulnar paralysis from the pressure of a displaced fragment of the head of the radius This curious displacement is more readily understood when it is recognised that the primary injury was a dislocation of the elbow Figure 884 shows a backward dislocation with comminution of the radial head After manipulative reduction some of the fragments lay near their normal position but half the head of the radius was left stranded on the inner side of the joint All the fragments were removed through incisions on the inner and outer sides of the joint and an almost normal range of movement was regained (Figs 885-887)

Dislocation of elbow joint with avulsion of the medial epicondyle—Lateral dislocation of the elbow joint may be associated with avulsion of the epiphysis of the medial epicondyle—these injuries have been discussed on page 844 There is often ulnar paralysis from traction injury of the nerve Care must be taken in reducing the dislocation to avoid inclusion of the epiphysis on the inner side of the joint (Fig 874) Later treatment

FIG. 885

FIG. 886

FIG. 887

Dislocation of elbow with fracture of head of radius

The original injury is seen in Figure 884. After reduction of the dislocation there are many fragments of the head of the radius on the antero-lateral aspect of the joint, and one on the medial aspect (Fig. 885). All these fragments must be excised at an early stage of treatment (Fig. 886). A good range of painless movement may then be expected (Fig. 887).

which was then blood caked and hard as concrete was also cut It was the hard blood clotted wool that had been at fault and this caused irreparable Volkmann's ischæmic contracture In emergency measures every layer of plaster wool or bandage right down to the skin must be cut and separated so that the pressure is released without any doubt

Duration of immobilisation—In children, fractures of the radius and ulna are usually united in six weeks In adults, immobilisation should be continued for at least ten weeks The short periods of immobilisation often recommended for forearm fractures are the cause of the non union which is sometimes seen When there is a fracture at the junction of the middle and lower thirds of the ulna it is unsafe to remove the plaster until there is radiographic evidence of union At this level slow union from loss of blood supply of the distal fragment is seen very often, but if immobilisation is continued for a sufficiently long time the complication of non union can always be avoided

Complete plaster until the fracture is united—At no stage before the fracture is firmly united should the plaster be cut down at the elbow level A short forearm plaster does not prevent rotation stresses on the fracture of the ulna indeed, by limiting movement at the inferior radio-ulnar joint and allowing it at the superior radio-ulnar joint rotation strains of the fracture are actually increased A short forearm plaster or a leather guard for the forearm is more dangerous than no plaster at all (see pages 25-26)

Greenstick and crack fractures are often sustained by children There may be no displacement or no more than a few degrees of angulation which is corrected easily by firm but controlled moulding Greenstick fractures should not be reduced by sudden jerking uncontrolled movements because in this way the injury may be converted into a more difficult complete fracture with over riding of the fragments Immobilisation is needed for three weeks in simple greenstick injuries and for five or six weeks if the fracture is more complete A plaster cast should be applied from the metacarpal heads to the upper arm with the elbow at the right angle and the forearm in supination or the mid position according to the level of fracture If the alignment is found to be imperfect it should be corrected by wedging the plaster (page 171)

Treatment of forearm fractures with the elbow fully extended—Fractures of the shafts of the forearm bones should usually be immobilised with the elbow at the right angle When the fractures lie high in the upper third of the forearm the flexed position of the elbow may cause backward angulation of the fragments the limb tends to flex at the site of fracture as well as at the elbow joint The angulation may develop only as swelling of the elbow subsides about ten to fourteen days after reduction Fractures at this level are most easily treated with the elbow in full extension Traction should be applied to the limb with the elbow straight a plaster cast being applied in the usual way from the metacarpal heads to the axilla The position of full extension of the elbow may be used for any forearm fracture with backward angulation which is difficult to control it is then easy to judge when angulation is completely corrected There will be little or no difficulty in regaining full elbow movement

Operative reduction of fractures of the shafts of the forearm bones—If a perfect position is not secured by manipulation the surgeon whose aseptic

Fig 888
Ten days old fracture-dislocation of the elbow joint.

Fig 889
Radiographs with portable apparatus show accurate reduction.

technique can be relied upon should not hesitate to undertake operative reduction[1,2] The ulna is approached through an incision over its subcutaneous border The radius in the lower two-thirds of its shaft is exposed from the antero-lateral aspect the extensor carpi radialis muscles and the brachio-radialis being retracted backwards In the upper third, special care must be taken to protect the posterior interosseous nerve and the exposure described by Henry should be used[3] He has described many brilliant exposures of the shafts of long bones and this is one of the most brilliant of all Every surgeon who embarks on the operative treatment of fractures of bones should first study Henry's Exposure of Long Bones[4] In exposing the upper third of the shaft of the radius the tendon of biceps should be traced down to the tuberosity of the radius and the supinator muscle then be peeled off the bone from this point and retracted outwards thus carrying safely the posterior interosseous nerve within its substance Sometimes the fragments can be locked securely (Figs 898 899) but usually internal fixation is needed—see pages 198-201 There may be need for a single screw a plate and screws or an onlay graft (Figs 329 335)

Internal fixation of fractures of the forearm bones with immediate active mobilisation—In recent years many surgeons have advocated internal fixation of fractures of the shafts of both forearm bones by plates and screws without the external protection of plaster or splints After operation the limb is supported in a sling and early active movement is encouraged These surgeons have often succeeded and in this upper limb fracture where there are no weight bearing strains sound union has been achieved in most cases without the delay that arises from plaster immobilisation But surely it is not enough to secure sound union in *most* cases Certainly if I was one of the 10 per cent of patients who as a result of this programme developed non union of the fracture needing yet another operation and a complicated bone-grafting procedure I would have no interest in the other 90 per cent whose recovery had been accelerated by a few weeks I would be indignant to be asked to pay such a penalty for their small prize Let us not be blinded by the attraction of recovery in eight weeks instead of twelve weeks —what does that matter ? Let us be sure that all fractures unite—and this can be assured if internal fixation with plates and screws is protected by the external support of plaster for a sufficient time

Radio-ulnar synostosis from cross union—If operative *reduction* is undertaken simultaneously on both forearm bones and the operation is performed carelessly cross union may result This complication is the result of failure to suture the periosteum accurately The subperiosteal hæmatomas of the two fractures communicate and a bridge of bone develops which completely limits radio-ulnar movement This is to be avoided by operating whenever possible on one bone only When it is essential to expose both bones two separate incisions should be made one on each side of the limb and special care should be taken in suturing the periosteum If cross union has already occurred the bridge should be excised—but not until after the stage of active ossification when the new bone is consolidated

[1] Sowler, H K "End Results of Fractures of Both Bones of Forearm" (422 fractures 41 operative reductions) *J Bone Joint Surg* 1934, 16, 191.
[2] Buxton, St J D "Closed Fractures of Radius and Ulna." *Brit med J*, 1939 2, 795.
[3] Henry A K "Complete Exposure of the Radius." *Brit. J Surg* 1926 13, 506.
[4] Henry A K "Extensile Exposure" E. & S Livingstone Edinburgh, 1945.

is the same as for uncomplicated dislocations operative replacement of the epiphysis is not needed despite the frequency of fibrous and not bony union

Dislocation of the elbow joint with fracture of the back of the condyles— When the forearm bones dislocate backwards they may break off and carry with them the back of the lateral condyle of the humerus Such a case was reported by Howard [1] in an Italian labourer the displacement was unreduced and there was almost complete ankylosis of the joint In the case of the patient whose radiographs are shown in Figure 888 reduction was made difficult not only because eleven days had elapsed since injury but because he had no hand or lower forearm—it had been amputated some years before Despite the amputation he had worked as a general labourer and was anxious to get back to his job after this injury sustained from slipping on a piece of orange peel By sustained traction on the stump for several minutes and then gradual flexion of the elbow a satisfactory reduction was gained (Fig 889) Eight weeks later the patient discharged himself from the clinic and went back to work at the docks, he had full flexion movement and at that time limitation of extension by 30 degrees Let it never be said that British workmen cannot work

RECURRENT DISLOCATION OF THE ELBOW JOINT

Recurrent or habitual dislocation of the elbow joint is very rare indeed but of course recurrence after a first dislocation may occur in any joint if its stability is impaired by unsound healing of avulsed capsule or fractured marginal fragments of bone It is described in these pages in the shoulder, the sterno-clavicular joint the costo-chondral joints carpal joints cervical spine the hip ankle and toes—and why should the elbow joint be an exception? It is possible that there may sometimes be predisposition to recurrent displacement by abnormal shallowness of the trochlear notch of the ulna but as a rule recurrent backward dislocation of the elbow joint occurs from unsound healing of the anterior capsule at its attachment to the coronoid and especially from an un united fracture near the base of the coronoid which impairs the integrity of the trochlear notch Such an injury was illustrated in 1899 by Helferich [2] although he may not have recognised its significance in causing recurrent displacement Several examples of recurrent dislocation of the elbow have been published with accounts of successful operations Probably the best is that of Reichenheim [3] who transferred the distal insertion of the biceps tendon from the radius to a rawed area over the front of the base of the coronoid It may be still better to use the modification of King [4] who passed the tendon through a drill hole in the coronoid and stitched it to soft tissues over the back of the olecranon Other methods of anterior capsular plication [5] fascial or tendon repair of the capsule [6-7] or anterior bone block [8-10] have succeeded but the technical difficulties are greater

[1] Howard, N J "Epiphyseal Fracture-dislocation at Elbow Joint." J Bone Joint S rg., 1935 17, 1[illegible]
[2] Helferich, H "On Fractures and Dislocations. Translated 3rd ed., London, 1899 Sydenham Society
[3] Reichenheim, P P Brit J S rg 194[illegible] 35, 201.
[4] King, T J Bone Joint rg 19[illegible], 35-B, 50.
[5] Knoflach, J G Zentralblatt f Chir., 193[illegible] 62, [illegible]
[6] K pel, O J Bone Joint rg 19[illegible] 33-A, [illegible]
[7] Spring, W L J Bone Joint S rg 19[illegible] 35-B, 5[illegible]
[8] Milch, H J Bone Joint urg 1936, 18, [illegible]
[9] Wainwright, D Proc Roy Soc Med. (Section Orthop.), 1947 40 [illegible]
[10] Hall, R. McK. J Bone Joint Surg., 19[illegible] 35-B, 56.

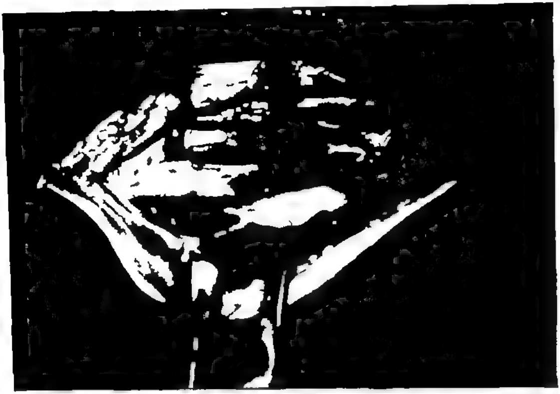

FIG 898

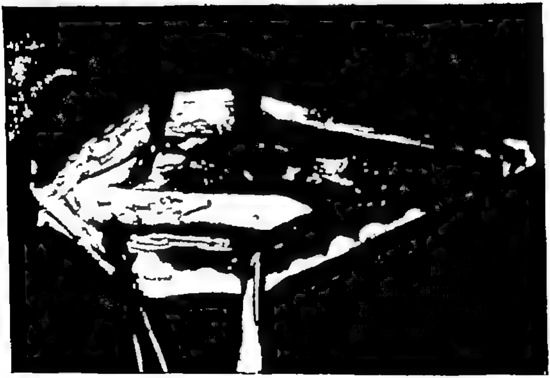

FIG 899

Fracture of the shafts of both forearm bones. Manipulative reduction secured accurate replacement of the ulnar fragments but failed to reduce the radius. After operative exposure the fragments interlocked very securely; it was a stable type of fracture, with no radio-ulnar dislocation; internal fixation was therefore unnecessary

FIG 890

FIG 891

The history suggested that the limb was normal until an injury was sustained a few weeks before; operative reduction with reconstruction of the orbicular ligament was being considered. But radiographs show that the dislocation is many years old and very probably congenital. There is typical deformity of the radial head, and the posterior outline of the ulna curves forwards from the olecranon whereas normally it curves backwards (B. McFarland, "Congenital Dislocation Head of Radius. *Brit J Surg.*, 1936, 24, 41). There was little disability and no indication for operation. *(By courtesy of Surgeon Lieutenant H A Jewell)*

FIG 000

FIG 001

Grossly comminuted fracture of the shafts of both forearm bones with destruction of sk from above the elbow *to the lower third* of the forearm (Fig. 000). The first problem w the replacement of skin the *second* was re-alignment and grafting of the forearm bone the third was reconstruction by excision of the head of the radius and the lower end of tl ulna (Fig 001—see text).

UNUSUAL DISLOCATIONS OF THE ELBOW

Forward dislocation of the radius or of both forearm bones, at the elbow—Traumatic dislocation of the head of the radius is nearly always part of a Monteggia fracture-dislocation in which there is also fracture of the upper shaft of the ulna (p 572) Care must be exercised in accepting the diagnosis of isolated dislocation of the radial head because there is so often a fracture of the ulna Moreover, there may be confusion with congenital dislocation of the radial head (Figs 890 891) Isolated traumatic dislocation of the upper end of the radius does sometimes occur without fracture and in exceptional cases there may even be forward dislocation of *both* forearm bones without fracture There is one case in which there can be no doubt about it the joint was dissected after the limb had been amputated—but that was long ago [1]

Divergent dislocation of the forearm bones at the elbow—In the latter half of the last century there were many case reports of divergent dislocation of the forearm bones at the elbow Stimson [2] clearly defined two types 1) dislocation of the ulna backwards and the radius forwards , 2) dislocation of the ulna medially and the radius laterally There were also many reports of so-called isolated rotary dislocation of the ulna in which the ulna was said to have rotated backwards while the radius remained undisplaced There are scores of references to these supposed displacements [3] but so far as I can judge from study of this literature—much of it eighty or ninety years old—it is no more than a relic of the day when surgeons had to do the best they could with clinical examination without the aid of X ray examination They were nearly all ordinary dislocations of both forearm bones and almost without exception the reports ceased at the turn of the century after Röntgen s discovery of X rays But before dismissing these displacements the reader should look at Figures 936-937

Canton, E. "Dislocation of the Ulna Forwards without Fracture of the Olecranon." *Dublin Quart J med. Science*, 1860, *n.s.* 30, 24.
Stimson, L. A. "Treatise on Fractures and Dislocations." Translated 3rd ed. (and copied 4th ed., 1905, and 8th ed., 1913). London, *Henry Kimpton*, 1901

Divergent and isolated rotary dislocation of ulna—Not one of the many articles I have traced which were said to report "Isolated Rotary Dislocation of the Ulna or Divergent Dislocation of the Elbow showed evidence of more than ordinary dislocation of both forearm bones. Even the two articles published in this century included only worthless single X-ray projections which in one at least had obviously been misinterpreted (Warbasse, J P., *Ann. Surg.*, 1910, 52, 216, and Wampler F J., *Ch ne med J.*, 1920 34, 604). The rest were published in the last century and had no radiographs at all (Sedillot 1839 Diday 1839 Michaelis 1840 Brun 1844 Wildhorn 1846, Mayer 1848 Uhde 1857 Bauchet 1861 Isaacs 1863, Arnozan 1873 Bridges 1874 Fenq 1877 Minich 1880 Nicolich 1880 Wright 1882, Montagnon 1880 Lawson 1890, Porquier 1890 Mimervini 1893, Neulasser 1900).

OPEN AND INFECTED FRACTURES OF THE FOREARM BONES

Throughout its length the ulna lies in a subcutaneous position and when it is fractured one fragment often perforates the skin Technically this is an open fracture and the wound should of course be excised under suitable chemotherapeutic control but since there is neither crushing nor contamination of muscles there is really no problem of treatment—after a simple operation it may be treated as a closed injury

Open fractures of the forearm—The real difficulty arises when the forearm bones are crushed and mutilated with destruction of skin and contamination of damaged muscles Such a case is shown in Figures 900 901 A sergeant-pilot crash landed and fractured his forearm The bone injury was a double fracture of the shaft of the radius with vertical splitting of the central fragment a double comminuted fracture of the shaft of the ulna, a comminuted fracture of the head of the radius and delayed dislocation of the inferior radio ulnar joint But the fractures and dislocations were almost the least of his injuries—there was also musculo-spiral paralysis and avulsion of skin from the elbow joint and upper half of the forearm except for a narrow isthmus behind After resuscitation and excision of the wound the urgent problem was replacement of skin and this was done the next day Forty-eight square inches of skin were transferred by razor grafts from the thighs Two months later reconstructive bone surgery was begun and it was completed in three separate operations first the fragments of the shaft of the ulna were fixed by an onlay graft then the fractured head of the radius was excised and the fragments of the radial shaft were replaced and secured by another onlay graft and at a third operation the dislocated lower end of the ulna was excised What was the result of treatment of this forearm injury which in earlier years would almost certainly have been amputated on sight ? The patient went back to flying duty as a pilot and he went back *within ten months of injury* The fractures were sustained on 10th August 1941 and flying duties were resumed on 10th July 1942 [1]

Infected fractures of the forearm—If infection is already established and bone is sequestrated different reconstructive measures are needed Figure 902 shows a double fracture of the shaft of the radius treated elsewhere in which operative reduction with wiring of the fragments had been complicated

[1] *Murray Meekison of Vancouver*—This case report is the least tribute that orthopaedic surgeons of the Royal Air Force can pay to the memory of Murray Meekison who came earlier than other Canadians to join our orthopaedic service in the last war He died in our service, only reaching home a few months before his final anginal attack. His amazing success in the treatment of this patient, aided by Group Captain George Morley who did the skin grafting, was, of course, equalled by others, but never with greater command of affection. Let me quote one of his operation notes on this patient dictated in November 1941 which is in the official Air Ministry records: "Fibrous tissue and junk were dissected from between the fracture ends and finally the ulna was lined up. A graft was then removed of correct length from the tibia, and drill holes were placed in the graft while still in the tibia. Then the saw broke down. The saw-chock which had been sent in August for repair and was still in the Quartermaster's department, was brought up and sterilised and the grafts were made This chock produced a very eccentric movement of the saw The eccentricity of the chock caused the saw to pick up the towel over which the surgeon was working with the result that the graft fell on the floor The graft was boiled and screwed firmly in position with four vitallium screws The arm wore a tourniquet for two and three-quarter hours. Patient's post-operative condition is excellent It was a typical Meekison operation note—querulous and inconsequential, but always good-humoured—and as this case proves he certainly got the results. He was our devoted friend.

CHAPTER XXI

INJURIES OF THE FOREARM

The commonest bone injuries of the forearm are 1) fractures of the shafts of the radius and ulna 2) fracture of the shaft of the ulna with dislocation of the upper end of the radius 3) fracture of the shaft of the radius with dislocation of the lower end of the ulna There are, of course other combinations of injury which will be discussed in this chapter—but let it be said at once that fracture of the shaft of one forearm bone with over riding and angulation but without corresponding fracture of the other forearm bone, must necessarily be associated with dislocation of one of the radio-ulnar joints. Failure to recognise this simple fact has caused many serious disabilities when displaced fractures of the upper shaft of the ulna have been treated without recognising the dislocation of the upper end of the radius, and when displaced fractures of the lower shaft of the radius have been treated without knowing that there was also a dislocation of the lower end of the ulna

FRACTURES OF THE SHAFTS OF BOTH FOREARM BONES

It is important that the angulation of fractures of the shafts of the forearm bones should be corrected The superior and inferior radio-ulnar joints rotate in parallel planes in much the same way that the wheels of a car rotate in parallel tracks If the axle of the car is bent the wheels cannot move normally and if the forearm bones are angulated the radio-ulnar joints cannot move normally For this reason even slight angulation of the shafts of the radius or ulna may cause permanent limitation of pronation and supination movement

A second type of displacement also limits radio-ulnar movement The biceps and the supinator brevis which are the strong supinator muscles of the forearm are inserted into the upper third of the shaft of the radius. The pronator teres is attached to the middle third of the bone and the pronator quadratus to the lower third. A fracture of the shaft of the radius situated at the junction of the upper and middle thirds lies between the two groups of muscles the proximal fragment has only supinator muscles attached to it and the distal fragment has only pronator muscles (Fig 89*) One fragment is therefore supinated and the other fragment is pronated there may be from 90 to 180 degrees of rotational displacement Figure 894 shows the typical deformity There is not only backward angulation of the fragments but the hand and lower forearm are almost fully pronated whereas the upper forearm is supinated radio-ulnar movement is completely limited The rotational displacement is shown clearly in Figure 895 where although the fragments may appear to be in good position in the lateral radiograph the antero-posterior radiograph shows striking discrepancy in the width of the interosseous space between the distal fragments as compared

Fig 902

Fracture of the shaft of the radius at two levels with infection and sequestration of the central fragment.

Fig 903

Fig 904

The problem of destroyed bone was met by radio-ulnar transference (grafting the distal fragment of the radius into the shaft of the ulna—Hey Groves) There was still the problem of complete destruction of all extensor muscles which was met by transplantation of a flexor muscle (Figs 905-906)

Figs. 905-906

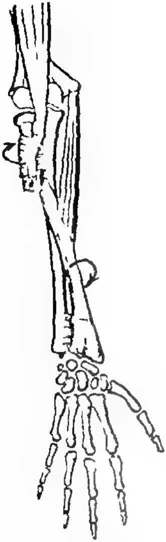

FIG 802

In a fracture of the upper shaft of the radius the proximal fragment is supinated and the lower fragment is pronated

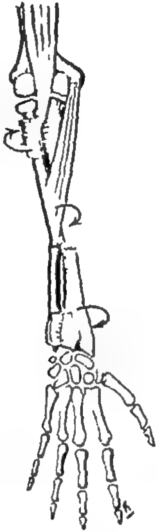

FIG 803

In a fracture of the middle or lower shaft the proximal fragment is in the mid position and the lower fragment is pronated

FIG 804

Mal-united fracture shaft of radius showing typical displacement with pronation of the lower fragment and backward angulation

by grave infection so that a large part of the shaft of the radius lay exposed in the wound The extensor muscles of the forearm were destroyed and there was drop wrist After the dead bone had been removed as a first step in healing the infection most of the radius was missing, and the remaining fragments were so porotic that it would have been difficult indeed to secure sound fixation of bone grafts (Fig 903) In such forearm injuries the operation described by Hey Groves [1 2] of constructing a single radio-ulnar bone may be advisable In this case of a young farmer s boy the lower shaft of the ulna was impaled into the distal radial fragment Care was taken to fix the new single forearm bone slightly on the pronated side of the mid radio ulnar position (Fig 904) The flexor carpi ulnaris was later transplanted to the distal extensor tendons of fingers and thumb, and function is now so good that the boy is engaged as a farmer and has already taken over most of his father s arduous duties (Figs 905-906)

UN-UNITED FRACTURES OF THE FOREARM BONES

Non union of fractures of the lower shaft of the ulna nearly always arises because the immobilisation of a recent fracture has been inadequate Usually the above-elbow plaster cast has been changed to a below-elbow cast at too early a date this was discussed in the first volume on page 25 It is in fact easy to prevent non union of these fractures by suitably prolonged treatment the immobilisation being continued for three or four months or sometimes even for eight or ten months But in other fractures of the radius and ulna there may be difficulty especially when the shafts of the bones have been destroyed by gun-shot or shell wounds or by infection Bone-grafting procedures may then be needed

There is no difficulty in treating un united fractures of the lower shaft of the ulna After refreshening the fractured surfaces and removing a thick shaving of cortical bone an onlay graft is cut from the tibia and applied with screw fixation two screws in each fragment Similarly an onlay graft may be needed for many other un united fractures of the shafts of the forearm bones One example is shown in Figures 900 901 and an even more difficult case of non union persisting over many years despite repeated operation treated successfully by onlay grafts was illustrated on page 331 Whole thickness onlay tibial grafts are often needed when there has been extensive destruction of bone with wide gaps between the fragments But at the same time the general principle must be observed that if there is active or even potential infection cortical bone transplantation or screw fixation is to be avoided There could be no more clear example of this than the case illustrated in Figures 560 564—cortical onlay grafting with screw fixation failed but cancellous chip grafting succeeded

For un united fractures of the upper shaft of the ulna intramedullary nail fixation with cancellous bone grafting may be excellent the olecranon providing ready access for the insertion of a nail but intramedullary fixation is seldom wise in un united fractures of the radius Here it is better to use an onlay graft with four screws or if there is threat of infection cancellous bone grafts cut from the ilium without metallic internal fixation

Groves Hey "Modern Methods of Treating Fractures," 2nd ed., p 330. Bristol.
Greenwood, H H. "Reconstruction of the Forearm." Brit J Surg., 1932, 20 6
Watson-Jones R. "Reconstruction of Forearm." Brit. J Surg., 1934 22, 23

with the space between the proximal fragments The proximal fragments are in the supinated position, the distal fragments are pronated and there is at least 90 degrees of *rotational* displacement between them Fractures of the upper third of the radius should therefore be immobilised with the hand and forearm supinated so that the distal radial fragment is *rotated*

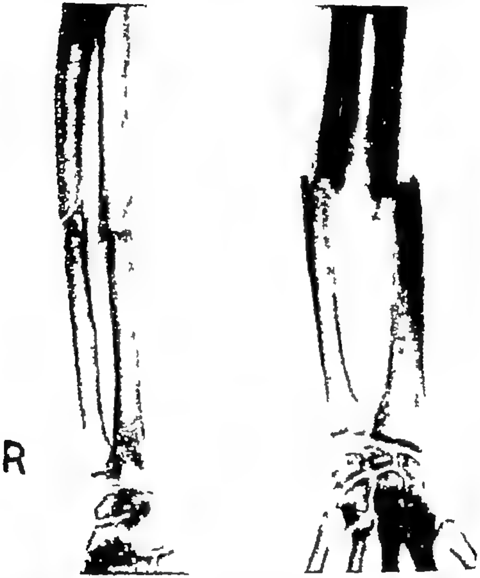

FIG. 893

Radiographic diagnosis of rotational displacement may be difficult in fractures of the shafts of the femur and humerus, but it is easy in fractures of the forearm and leg bones where it is disclosed by the unequal width of the interosseous space in proximal and distal fragments. In Figure 893 the position appears satisfactory in the lateral view but in the antero-posterior view it is obvious that the distal radial fragment is much more pronated than the proximal.

into the same axis as the proximal fragment[1] If the fracture is at or below the middle third of the radius the proximal fragment has both supinator and pronator muscles attached to it it is turned into a mid position half way between full supination and full pronation—and at these levels forearm fractures should be immobilised with the hand and lower forearm in the mid position

[1] Evans, E. M. "Fractures of the Radius and Ulna." *J. Bone Joint Surg.*, 1951, 33-B, 548.

FRACTURE OF THE UPPER SHAFT OF THE ULNA WITH DISLOCATION OF THE RADIAL HEAD

Monteggia Fracture-dislocation

More than a century has passed since Monteggia described a fracture of the upper shaft of the ulna with dislocation of the head of the radius, but it has taken more than a century to find a solution to the problems of treatment of this injury [1] Few *fracture-dislocations* are beset with greater difficulty and few have been characterised by so many complications Until recent years there was residual disability in nearly every case The special complications included mal union of the fracture of the ulna non union of the fracture of the ulna, unreduced dislocation of the radial head traumatic ossification round the radial head cross union between the forearm bones at the level of fracture and subluxation or dislocation of the lower end of the ulna with limitation of movement of the wrist To this formidable list of special complications there must of course be added the ordinary complications of nerve injury vascular disturbance, wound infection and so forth In one consecutive series of thirty four Monteggia fracture-dislocations sustained by adults and treated by many surgeons which I studied in 1940 there were only two good results thirty two of thirty four patients had *serious permanent disability*

Thus the first important observation to be made is that the difficulties of treatment of this injury are so great that a surgeon who is not yet widely experienced in the treatment of fractures should have no hesitation and feel no regret in arranging prompt transfer of the patient to a more experienced colleague the time will come when others should arrange similar transfer to him

The second point to be emphasised is that although a fracture of the upper shaft of the ulna is usually obvious an associated dislocation or subluxation of the head of the radius may be overlooked so that the fracture-dislocation is then treated as if it was an isolated fracture (see page 145) Every fracture of the upper shaft of the ulna unaccompanied by fracture of the shaft of the radius should at once be suspected as being part of a Monteggia fracture-dislocation Certainly if there is angulation or over riding of the fragments of a fractured ulna without corresponding injury to the radius there *must* be a dislocation of the radial head

The third fact to recognise is that Monteggia fracture-dislocations may occur from either *flexion* or *extension* stresses and that there are two corresponding types of injury (Figs 907 910) *Flexion fracture-dislocations* account for only 10 or 15 per cent of cases the fractured ulna is angulated backwards and the head of the radius is dislocated backwards, manipulative reduction is stable and operative treatment is seldom needed In *extension fracture-dislocations* the fractured ulna is angulated forwards and outwards and the head of the radius is dislocated forwards and outwards reduction is unstable and internal fixation of the ulna is nearly always needed It should be added that in such operative reduction there must be care to avoid cross union between the forearm bones to prevent traumatic ossification

[1] Monteggia, G. B. Instituzioni chirurgiche 2nd ed. Milan G. Maspero, 1814.

Fractures of the shafts of the radius and ulna—*Manipulative reduction*—Over riding and angulation of the fragments should be corrected by sustained traction[1]. Many fractures of the forearm bones cannot be reduced by the brief and perfunctory manipulation sometimes adopted. The fractured surfaces are often irregularly shaped and there may be projecting spikes which disengage only when the limb is slightly over lengthened. It may be necessary to continue the traction for two or three minutes before the fragments slide into accurate end to-end position. Complete apposition of fragments is important because otherwise the reduction of forearm fractures is unstable and there may be redisplacement even in a closely fitting plaster cast. Counter traction is arranged by passing a sling of calico bandage over a pad of wool in front of the lower arm just above the elbow fastened to a hook in the wall. If the patient's fingers are moist and slippery they may be covered with adhesive strapping which gives a more secure grip. Traction is applied by taking the thumb in one hand and the fingers in the other; it is continued until radiographic examination shows that full length has been restored and that the fragments are in accurate apposition. The traction is maintained while a plaster slab is lightly bandaged to the limb. It extends from the metacarpal heads to the shoulder, passing through the loop of the calico sling and up the back of the arm (Fig 890). When the plaster is set the sling is removed but the wool pad in front of the elbow remains and the cast is completed by encircling turns of plaster bandage. While the plaster is setting light pressure is applied to the front and back of the forearm so that the cast will be oval and not round in section and in this way separation of the bones from the interosseous space will be maintained. It is unwise to indent the plaster between the bones by the pressure of fingers or by bandaging pegs of wood on the surface of the plaster before it is set because pressure sores are often produced in this way. Such methods of treatment are fraught with danger.

After treatment—Further radiographs are taken when the plaster is completed and if any trace of angulation remains it is corrected by wedging the plaster. Even in unpadded casts there is some danger of redisplacement of the fragments. This can be avoided by accepting only a perfect initial reduction by changing the plaster after two or three weeks when swelling of the limb subsides and by examining check radiographs every second or third week during the first two months. If there is evidence of redisplacement from looseness of the plaster a new cast should be applied at once.

Circulation of the fingers and Volkmann's contracture—During the first few days the hand should be elevated with the fingers pointing to the ceiling in order to minimise reactionary swelling. Finger and shoulder exercises are begun at once and practised regularly throughout the period of immobilisation. The circulation and movements of the fingers must be watched with special care because ischæmic contracture of the forearm muscles is almost as common in fractures of the shafts of the radius and ulna as in injuries of the elbow joint. If there is persistent cyanosis or pallor of the fingers or limitation of passive extension from contracture of the flexor muscles the plaster should at once be cut throughout its length from the front of the wrist to above the elbow. It may be repaired after a few days when there is no longer danger of circulatory embarrassment.

[1] Carrell, W. B., "Fractures of Both Forearm Bones." *Surg. Gyn. Obstet.*, 1933 **56**, 506.

round the head of the radius and to avoid early excision of the radial head which causes spontaneous dislocation of the inferior radio ulnar joint

Before considering treatment the mechanism of injury may be discussed although it is probably of little more than academic interest Mervyn

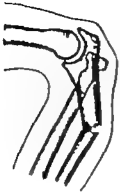

Fig 907

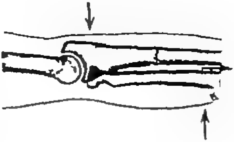

Fig 908

Monteggia fracture-dislocation—flexion type

Fracture shaft of ulna with backward dislocation of the head of the radius. The displacement is reduced by applying traction to the forearm with the elbow fully extended It is immobilised in extension.

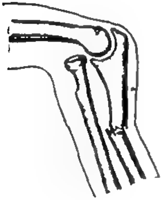

Fig 909

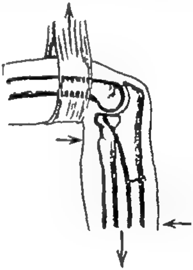

Fig 910

Monteggia fracture-dislocation—extension type

Fracture shaft of ulna with forward dislocation of the head of the radius. The displacement is reduced by applying traction to the forearm with the elbow flexed. It is immobilised in flexion.

Evans suggested that these fracture-dislocations were always sustained from falls on the outstretched hand with twisting of the trunk which forcibly pronated the forearm [1] With the support of experimental studies he claimed that anterior dislocation of the head of the radius with or without fracture of the ulna was a forced pronation injury that full supination was essential

[1] Evans, E. M. "Pronation Injuries of the Forearm." *J Bone Joint Surg* 1949 31-B, 579.

Fig 806

Reduction and immobilisation of fracture of the shafts of the forearm bones. Traction is maintained against the counter pull of a calico sling After reduction a plaster slab and cast are applied

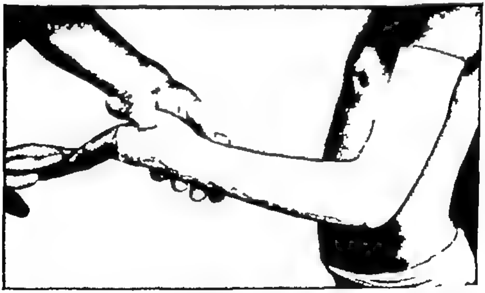

Fig 807

Completed plaster for fractures of the forearm bones. The operator is testing for flexion contracture of the fingers, one of the signs of ischaemic contracture of the muscles from a tight plaster

One of the most unfortunate and at the same time instructive of recent cases was a patient on whom I operated for fractures of the shafts of both forearm bones Later that night embarrassment of circulation was recognised and the house surgeon rightly cut the plaster from wrist to shoulder—but it was not until twelve hours later that the underlying wool

for reduction as well as a safeguard against recurrence of displacement and that even difficult extension fracture-dislocations were stable if the forearm was immobilised in full supination I can say only that this injury does not always arise from forced pronation and that immobilisation in supination is not always a safeguard except perhaps in children [1] Monteggia fracture-dislocation is a common injury in Africa and many surgeons in that continent have experience of sixty or eighty cases nearly all these injuries being sustained by natives who raise an arm to ward off a blow thus sustaining direct violence on the back of the upper forearm so that the ulna is comminuted and angulated forwards and the head of the radius is driven forwards It may be that Monteggia fracture-dislocation is sometimes caused by the mechanism displayed in Mervyn Evans experiments, as well as by the direct violence so well known in Africa—but it matters not so long as the instability is recognised and the need for internal fixation of the ulna is accepted [2]

FIG 911

Fracture shaft of ulna with backward angulation and backward dislocation of the head of the radius.

FIG. 912

Same case after manipulative reduction. The limb was immobilised with the elbow in full extension for three months. Excellent movement was regained.

Treatment of the flexion type of Monteggia fracture-dislocation—It is usually possible to secure perfect alignment of the ulna because in extension of the elbow the fragments *lock in the reduced position* All that is needed is to apply traction extend the joint fully and immobilise it in plaster from the metacarpal heads to the axilla (Figs 911 912) Accuracy of alignment

[1] Naylor A. "Monteggia Fractures." *Brit. J Surg.*, 1942, 29, 323.
[2] Penrose J H. "Monteggia Fracture with Posterior Dislocation Radial Head." *J Bone Joint Surg* 1951 33-B 65

must be confirmed by radiographic examination in both antero-posterior and lateral planes, and if there is residual angulation it should be corrected by wedging the plaster operative reduction with internal fixation is seldom needed The plaster may need to be renewed from time to time but the position of complete extension of the joint should not be disturbed Any attempt to change the position of immobilisation to the right angle is inadvisable even if it is made several weeks after reduction. No position other than 180 degrees of extension should be used until the fracture is united because otherwise there will be recurrent angulation of the ulna and redislocation of the radius

Treatment of the extension type of Monteggia fracture-dislocation—Whereas flexion fracture-dislocations are replaced by extension of the joint extension fracture-dislocations must be replaced by flexion—but it is usually difficult to achieve complete reduction by manipulation alone The fragments do not readily lock in the reduced position, and even when initial reduction is satisfactory there is always a tendency to recurrence of outward angulation Open reduction with internal fixation of the ulna is needed Open reduction without internal fixation or with the inadequate fixation of strands of catgut or wire is useless because it fails to prevent redisplacement and at the same time it increases the stripping of periosteum which disperses the subperiosteal hæmatoma and increases the danger of traumatic ossification and cross union between the shafts of the radius and ulna (Figs 926-927) Very secure fixation is needed A vitallium or stainless-steel plate may be used with four screws of exactly the correct length so that they penetrate the opposite cortex without projecting beyond it (there is danger in using screws too long because subperiosteal ossification with cross union to the ulna may thus be encouraged)

Fixation by intramedullary nail—It is still better to use an *intramedullary* nail driven through the olecranon across the site of fracture and *into the* distal fragment After operation the limb should be supported in a plaster cast from the hand to the axilla and it may even be wise to apply a shoulder plaster spica The use of short above-elbow plasters with inadequate internal fixation has often caused non union of the fracture of the ulna If sound ternal fixation of the ulna is achieved by intramedullary nailing a plaster ist from the hand to the axilla may suffice but in other circumstances a ioulder plaster spica should be used for three or four months.

Danger of early open reduction of the dislocated radius—When the ulna is been re aligned it is seldom necessary to expose the dislocated head of ie radius it can usually be replaced by manipulation Operative exposure irries the risk of traumatic ossification

Danger of early excision of the head of the radius—It has been suggested iat in order to avoid limitation of radio-ulnar movement the head of the idius should be excised at the time that the ulna is reduced and plated. his is inadvisable not only because it increases the danger of traumatic ssification but because excision of the radial head at an early date before ie torn annular ligament and interosseous membrane have healed encourages ie shaft of the radius to slide up with dislocation of the lower end of the lna which must be excised Even then the stump of the upper end of ie radius may impact against the capitellum once more and need a second xcision (Figs 919 922) If the head of the radius is to be excised at all it hould be done as a late operation

FIG. 936

FIG. 937

Unusual fracture-dislocation of radius. The elbow joint had been dislocated and apparently reduced, but there is independent downward dislocation of the upper two-thirds of the radius (Fig. 936). It was necessary to redislocate the ulna before the displacement could be reduced by manipulation (Fig. 937). Note the avulsion of the internal epicondyle which gives the clue to the mechanism of injury. *Recovery was complete, all joints regaining normal movement.*

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[1] Naylor A. "Monteggia Fractures *Brit J Surg* 1942, 29 323

[2] Pearce J H. "Monteggia Fracture with Posterior Dislocation Radial Head." *J Bone Joint Surg* 1951 33-B, 65

FIG. 938

Comminuted fracture of the head of the radius sustained not by valgus strain of the joint but by longitudinal compression of the forearm.

FIG. 939

FIG. 940

Radiographs of the inferior radio-ulnar joint at the time of the initial injury (in the same case as shown in Fig. 938) prove that there had been longitudinal compression with subluxation of the inferior radio-ulnar joint—the Essex Lopresti type of fracture-dislocation (Fig. 939). The significance was not recognised so that, of course, early excision of the radial head increased the displacement at the inferior radio-ulnar joint (Fig. 940). The lower end of the ulna then had to be excised.

must be confirmed by radiographic examination in both antero posterior and lateral planes and if there is residual angulation it should be corrected by wedging the plaster, operative reduction with internal fixation is seldom needed The plaster may need to be renewed from time to time but the position of complete extension of the joint should not be disturbed Any attempt to change the position of immobilisation to the right angle is inadvisable even if it is made several weeks after reduction No position other than 180 degrees of extension should be used until the fracture is united because otherwise there will be recurrent angulation of the ulna and redislocation of the radius

Treatment of the extension type of Monteggia fracture dislocation—Whereas flexion fracture-dislocations are replaced by extension of the joint extension fracture-dislocations must be replaced by flexion—but it is usually difficult to achieve complete reduction by manipulation alone The fragments do not readily lock in the reduced position and even when initial reduction is satisfactory there is always a tendency to recurrence of outward angulation Open reduction with internal fixation of the ulna is needed Open reduction without internal fixation or with the inadequate fixation of strands of catgut or wire is useless because it fails to prevent redisplacement and at the same time it increases the stripping of periosteum which disperses the subperiosteal hæmatoma and increases the danger of traumatic ossification and cross union between the shafts of the radius and ulna (Figs 926-927) Very secure fixation is needed A vitallium or stainless-steel plate may be used with four screws of exactly the correct length so that they penetrate the opposite cortex without projecting beyond it (there is danger in using screws too long because sub periosteal ossification with cross union to the ulna may thus be encouraged)

Fixation by intramedullary nail—It is still better to use an intramedullary nail driven through the olecranon across the site of fracture and into the distal fragment After operation the limb should be supported in a plaster cast from the hand to the axilla and it may even be wise to apply a shoulder plaster spica The use of short above-elbow plasters with inadequate internal fixation has often caused non union of the fracture of the ulna If sound internal fixation of the ulna is achieved by intramedullary nailing a plaster cast from the hand to the axilla may suffice but in other circumstances a shoulder plaster spica should be used for three or four months.

Danger of early open reduction of the dislocated radius—When the ulna has been re-aligned it is seldom necessary to expose the dislocated head of the radius it can usually be replaced by manipulation Operative exposure carries the risk of traumatic ossification

Danger of early excision of the head of the radius—It has been suggested that in order to avoid limitation of radio-ulnar movement the head of the radius should be excised at the time that the ulna is reduced and plated This is inadvisable not only because it increases the danger of traumatic ossification but because excision of the radial head at an early date before the torn annular ligament and interosseous membrane have healed encourages the shaft of the radius to slide up with dislocation of the lower end of the ulna which must be excised Even then the stump of the upper end of the radius may impact against the capitellum once more and need a second excision (Figs 919 922) If the head of the radius is to be excised at all it should be done as a late operation

of the forearm as in the case shown in Figure 938 This man was pushing hard on a loaded truck with his wrist dorsiflexed and elbow extended when the truck was suddenly stopped the radius was driven forcibly against the capitellum and fractured at its upper end while at the same time the ulna was dislocated at its lower end This injury was made clear by the studies of Essex Lopresti[1] The true nature may sometimes be disclosed in radiographs of the elbow alone which show impaction of the neck of the radius into the middle of the comminuted fragments of the head with shortening but of course it is much better to prove it by taking radiographs of the inferior radio-ulnar joint (Fig 939) Indeed in every recent comminuted fracture of the head of the radius radiographs should be taken of the inferior radio-ulnar joint in order to learn whether the radial head has been comminuted from valgus strain of the elbow with rupture of the medial collateral ligament or from longitudinal compression of the forearm with rupture of the inferior radio-ulnar ligaments

In the management of fractures of the radial head with distal radio ulnar dislocation an important point of treatment arises because if the head of the radius is excised at the time of injury the shaft rides up and displacement at the lower radio-ulnar joint is increased (Fig 940) This is the one injury in which excision of a comminuted fracture of the head of the radius should be delayed—it should be delayed long enough for the tears of the interosseous membrane and inferior radio-ulnar ligaments to heal On the other hand the shattered radial head may be replaced by a plastic prosthesis It seems to me that this is the only indication for using a plastic substitute in the elbow after excising fractures of the radial head The results of excision after ordinary fractures are so excellent that replacement by a prosthesis which may or may not secure permanent attachment to living bone is no more than adventurous surgery but when dislocations or fractures of the radial head are associated with rupture of the interosseous membrane and of the ligaments of the inferior radio ulnar joint a good case can be made out for replacement of the excised radial head by a plastic substitute

[1] Essex Lopresti P "Fractures of the Radial Head with Posterior Radio-ulnar Dislocation." *J Bone Joint Surg.*, 1951 33-B, 244.

CASE ILLUSTRATING THE DANGER IN MONTEGGIA FRACTURE-DISLOCATIONS OF FAILING TO SECURE SOUND INTERNAL FIXATION OF THE ULNA—AND THE DANGER OF TRAUMATIC OSSIFICATION

FIG 913

Monteggia fracture-dislocation treated by open reduction of the ulna without internal fixation (which was a mistake) and by open reduction of the dislocated radial head (which was also a mistake because it caused traumatic ossification).

FIG. 914

FIG 915

End result in case shown in Figure 913. Traumatic ossification around the head of the radius caused serious limitation of movement (Fig 914). Note how extensively the upper end of the radius must be excised to restore radio-ulnar movement when this complication has arisen (Fig 915).

CHAPTER XXII

INJURIES OF THE WRIST

Fractures near the wrist joint from falls on the outstretched hand make one of the largest of all groups of bone injuries. Displacements of the lower radial epiphysis are sustained by children and adolescents; fractures of the carpal scaphoid bone occur in young men with greater frequency than generally recognised; fractures of the bases and shafts of the metacarpals are among the commonest injuries of working men; and fractures of the lower end of the radius are often sustained by middle-aged and elder women. Much of the time of a surgeon who treats fractures will be spent on injuries of the wrist—but although fractures near this joint are quite usual, sprains are unusual.

Sprains of the wrist.—It is true that falls on the hand may sometimes cause traumatic synovitis without bone damage but this injury is so rare and carpal fractures are so common and so easily overlooked that the diagnosis of sprained wrist should be accepted only with reserve. Fractures of the carpal bones cannot be excluded by antero-posterior and lateral radiographs alone. The examination must always include oblique projections repeated after two or three weeks, because important bone injuries may be concealed (see page 133). If it is certain that a sprained wrist is unaccompanied by fracture the injury may be treated by the simple support of an elastic bandage for about ten or fourteen days and recovery will be rapid and complete.

Traumatic tenosynovitis.—Traumatic tenosynovitis around the wrist, *especially of the extensor tendons of the thumb*, *sometimes* develops from repeated and stereotyped movements as in painting, farming, hop-picking, working on the assembly line, or from other actions involving grasp between the fingers and thumb with quick pronation-supination movement of the forearm.[1-3] Newcomers to such jobs and workers recently returned from holiday or sick leave are especially vulnerable. There is aching pain with slight swelling, and movements of the thumb are accompanied by "wash-leather creaking." Temporary rest from repetitive movement is the essential treatment. It is usually wise to apply a dorsal plaster cast for about ten days and then to support the wrist with an elastic bandage, the resumption of work being graduated. Oxaluria is occasionally a predisposing cause and care should also be taken to treat distant foci of infection such as carious teeth.

Tendovaginitis stenosans.[4-5]—Pain over the radial side of the wrist from

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Blood, W.: "Tenosynovitis in Industrial Workers." *Brit. med. J.*, 1942, 2, 468.
Flowerdew, R. E., and Bode, O. B.: "Tenosynovitis in Farm Workers." *Brit. med. J.*, 1942, 2, 367.
Taylor-Jones, T.: "Tenosynovitis in Untrained Farm Workers." *Brit. med. J.*, 1942, 2, 446.
De Quervain, F.: "Über eine form von chronischer Tendovaginitis." *Korresp.Bl. schweiz. Ärz.*, 1895, 25, 38...
Finkelstein, H.: "Stenosing Tendovaginitis at the Radial Styloid Process" (clinical review, microphotographs and full bibliography). *J. Bone Joint Surg.*, 1930, 12, 509.

CASE ILLUSTRATING[1] THE DANGER IN MONTEGGIA FRACTURE-DISLOCATIONS OF TRAUMATIC OSSIFICATION ROUND THE RADIAL HEAD EVEN WHEN OPERATIVE REDUCTION IS INEVITABLE

Fig 916

Monteggia fracture-dislocation in which manipulation reduction of the radial head was impossible because there was interposition of the capsule and orbicular ligament between the displaced radial head and the ulna.

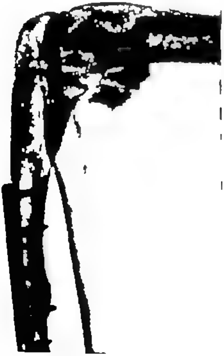

Fig 917

Fig 918

Same case as in Figure 916 Open reduction of the dislocated radial head caused traumatic ossification (Fig 917) necessitating later excision of the new bone and of the head of the radius (Fig 918). (*By courtesy of Mr Osmond Clarke*)

stenosing tendovaginitis often passes unrecognised The patient localises the pain at a point half an inch above the tip of the radial styloid process Inspection and palpation may not disclose any obvious abnormality Cursory examination of the wrist may seem to show no limitation of movement and the radiographs show no changes in the bone Treatment by massage and electrotherapy or by strapping and splinting is often prescribed, and yet the pain continues and increases When movements of the wrist are examined more carefully it is found that although they are painless when the thumb is left free, there is excruciating pain when the thumb is included within the surgeon's grasp and adducted to the ulnar side Careful palpation over the lower end of the radius discloses a small hard nodule about the size of a pea which is seldom visible (Fig 941) The disability arises from localised fibrosis with constriction of the sheath of the extensor

Fig 941

Stenosing tendovaginitis at the radial styloid process. A fibrous nodule involving the sheath of the extensor tendons of the thumb can be felt, and in this case seen, on the radial side of the wrist.

ossis metacarpi pollicis and the symptoms are at once relieved if the thickened sheath is excised

Peritendinous fibrosis of the dorsum of the hand—An intractable disability not yet understood may develop from a blow on the hand or sometimes after fracture of the metacarpal bones with thickening on the back of the hand which does not pit on pressure If the swelling is explored at operation it is found to consist of thickened hyperæmic fringes around the extensor tendons but excision of the inflamed tissues does not relieve the aching pain and the thickening usually recurs When firm pressure is maintained by a dorsal plaster cast the swelling subsides but unless support is continued for many months it often recurs once more In three cases it was possible to prove that the lesion had been caused by repeated self inflicted blows once in a neurotic girl and twice in men seeking compensation for injury but it is difficult to believe that this is the usual explanation It may be that peritendinous fibrosis of the back of the hand is related to adrenocortical or other hormonal dysfunction the fact is that we do not know

CASE ILLUSTRATING THE DANGER IN MONTEGGIA FRACTURE-DISLOCATIONS OF TOO EARLY EXCISION OF THE RADIAL HEAD—THUS CAUSING SUBLUXATION OF THE INFERIOR RADIO-ULNAR JOINT

FIG. 919
Immediately after operation.

FIG. 920
Three months after operation.

FIG. 921
Three months after operation

FIG. 922
Nine months after operation.

Early excision of the radial head may not only cause myositis ossificans, but if it is performed before the orbicular ligament and interosseous membrane have healed it causes sliding of the radius and dislocation of the lower end of the ulna (Figs. 921 922). Moreover the stump of the radius impacts once more against the capitellum (Fig. 920) and a second excision may be needed

COLLES FRACTURE OF THE RADIUS

The commonest fracture near the wrist joint was described in 1814 by Abraham Colles of Dublin [1] who pursued his studies in Edinburgh where was said that his landlady deliberately wasted his time talking lest h should read himself into a coffin. Seldom did a landlady find better excu for talking but at least this one succeeded in her self appointed task becau after Colles had received his Edinburgh degree he walked five hundr miles to London at the rate of fifty miles a day and at the astonishing early age of twenty nine was elected President of the Royal College Surgeons in Ireland His article on fracture of the lower end of the radi was published in the *Edinburgh Medical and Surgical Journal* [2] This fractu from falls on the outstretched hand is usual associated with backward and outwa displacement of the small distal fragme of the radius If the backward displaceme is left uncorrected there will be typi dinner fork deformity with restriction radio-ulnar movement because the distal e of the radius is displaced from the ul (Fig 943) and if the outward displaceme is left uncorrected there will be disfigureme from undue prominence of the lower end the ulna again with limitation of radio-uln movement Both backward and outwa displacements should be corrected.

Fig 942
Abraham Colles (1778-1843).
(*Reproduced from the "Journal of Bone and Joint Surgery"*)

Manipulative reduction—After suital treatment it should be impossible to kno which wrist has been fractured.[3,4] T commonest source of failure is imperfe correction of the radial displacement, a special care should be taken not only push and tilt the lower fragment forwa but also to press it strongly inwards towa the ulna It is unwise to disimpact the fragments by increasing the backwa displacement [5] because this may add to the injury of tissues over the fr of the wrist including the median nerve and the flexor tendons which already contused. There is no difficulty in disimpacting the fracture applying traction to the fingers and thumb and reduction of the displaceme can then be completed by direct pressure It may be possible to reduce bo displacements simultaneously by one twisting movement as described Robert Jones which pronates the lower fragment and pushes it forwards a inwards [6] but this manœuvre is liable to leave the outward displaceme imperfectly corrected. It is better to practise two distinct manipulatio To reduce a Colles fracture of the patient s right radius the surgeon shou grip the lower fragment in his left hand between his thenar eminence over t

Jones, A. Rocyn. "Abraham Colles." *J Bone Joint Surg* 1950 32-B, 126.
Colles, Abraham. "On the Fracture of the Carpal Extremity of the Radius." *Edin. med surg. J* 181
Platt, H Colles Fracture." *Brit. med. J.*, 1932, 2, 288.
Taylor G W., and Parson, C L. *Surg Gynec. Obstet.*, 1938 67 249 *J Bone Joint Surg.*, 1938, 20, 1
Charnley J The Closed Treatment of Common Fractures, page 77 Edinburgh E. & S. Livingstone, 1
Jones, Robert. "Injuries to Joints, page 110. Oxford University Press, 1915.

Treatment of the complications of Monteggia fracture dislocation—*Unreduced dislocation of the head of the radius*—Late unreduced dislocation is best treated in adults by excision of the displaced head of the radius. This removes the block of bone that otherwise limits flexion movement of the elbow and usually restores a good range of radio-ulnar movement. Excision of the head of the radius is not justified in children because it involves removal of the upper radial epiphysis with increasing inequality in the length of forearm bones and therefore dislocation of the inferior radio-ulnar joint; the head of the radius should be replaced with reconstruction of the orbicular ligament. Many surgeons have used free grafts of fascia lata.[1,5] Corbett used the bicipital fascia.[6] In two cases I have used tendon grafts, the

FIG. 923

FIG. 924

FIG. 925

Monteggia fracture-dislocation with mal-union of the ulna and unreduced dislocation of the radius in a child (Fig. 923). *A free graft of palmaris longus was used to maintain* reduction of the dislocation (Fig. 925).

palmaris longus in one and the peroneus tertius in the other—the tendon was passed round the neck of the radius and through a drill hole in the ulna. In the patient whose radiographs are shown in Figures 923-925 the effect of pressure of the newly constructed ligament can be seen in the ridging of bone in the final radiograph taken three years after operation. The position shown at that time is not quite as perfect as it was soon after operation, but good stability and a normal range of movement were maintained.

Traumatic ossification round the radial head—When early operative reduction of the dislocation has caused traumatic ossification the head of the radius and the block of bone attached to it must be removed. The new bone formation may be limited to a spur in front of the head and the operation then presents no difficulty, but sometimes there is ossification round the

Speed, K. Boox. "Fractures and Dislocations," 3rd ed. London: Henry Kimpton, 1935.
Wilson, P. D. "Management of Fractures and Dislocations." London: J. B. Lippincott Co., 1938.
Campbell, W. C. *J. Amer. med. Ass.* 1929, 92, 122.
Speed, J. S., and Boyd, H. B. *J. Amer. med. Ass.* 1940, 115, 1699.
Wardle, E. K. *Lancet*, 1941, 2, 520.
Corbett, C. H. *Brit. J. Surg.*, 1931, 19, 155.

back of the bone and fingertips over the front, and against the counter-pressure of his other hand on the front of the forearm tilt and push the fragment forwards the surgeon's right thenar eminence is then placed over the side of the patient's radial styloid process and with his left hand on the other side of the limb the fragment is pressed strongly inwards towards the ulna It is impossible to overcorrect the radial displacement by manual pressure—the only danger is that it will be undercorrected (Figs 944 946)

Comminuted Colles fracture—Comminution of the distal fragment of a Colles fracture makes it still more important to achieve complete reduction in order to prevent arthritis of the wrist joint The fragments should be compressed between the surgeon's two thenar eminences first in one plane and then in the other the fracture being treated thereafter as described above

Fig 943

Colles fracture of the radius showing the typical "dinner fork deformity due to backward displacement and tilting of the lower fragment

Immobilisation after reduction—When the fracture has been reduced an assistant should take the patient's thumb in one hand and the fingers in the other and maintain traction while a plaster cast is applied from the metacarpal heads to just below the elbow extending over the radial side of the thumb-metacarpal to the base of the thenar eminence and over the front of the wrist-joint to the scaphoid tubercle but not into the palm of the hand While the plaster is setting the surgeon again grasps the wrist, the fingers of his left hand reproducing the curve of the radial concavity in the plaster his right hand pushing the lower fragment of the radius inwards and forwards (Fig 947)

Preventing redisplacement—Reduction of a Colles fracture presents no difficulty but the application of a plaster cast tightly enough to prevent redisplacement and yet not so tightly as to interfere with the circulation demands skill and experience The porotic bone of an elderly patient is often so crushed that without careful treatment the radial displacement and backward tilting may recur This is to be prevented by accepting only perfect initial reduction (Figs 948-949) and by moulding the plaster carefully and applying a new plaster cast after about ten days

FRACTURE OF THE LOWER SHAFT OF THE RADIUS WITH INFERIOR RADIO-ULNAR DISLOCATION

In the same way that fractures of the upper shaft of the ulna are often associated with dislocations of the upper end of the radius fractures of the lower shaft of the radius are often accompanied by dislocations of the lower end of the ulna This typical fracture-dislocation of the lower forearm, with inward angulation of the radius and dislocation of the inferior radio-ulnar joint shows the same tendency to redisplacement even after successful primary reduction as the corresponding fracture-dislocation of the upper forearm Careful moulding of the plaster may sometimes suffice as in the case shown in Figures 930 931, but it is to be noted that even in this case careful manipulation reduction with plaster fixation had to be controlled by later wedging of the plaster In former years attempts were made to prevent redisplacement of this fracture-dislocation by applying continuous traction to the thumb with all its penalties of joint stiffness Methods of treatment by skeletal transfixion were also devised—pins being driven through the radius into the ulna after reduction It is far better to acknowledge that if manipulative reduction with suitable after treatment does not succeed the need for operative reduction with internal fixation should be accepted Through a short incision over the lower shaft of the radius on its postero-lateral aspect the fragments are exposed and replaced in correct apposition Very often secure fixation can be gained by driving in one screw placed obliquely across the fragments (Figs 932 933)—but it must be acknowledged that this is not always easy It is sometimes difficult to engage a single screw equally in both fragments In these circumstances a plate with four screws two in each fragment should be used (Figs 339-335 in the first volume) But even this is better than skeletal transfixion with its danger of infection or continuous thumb traction with its danger of stiffness

Un-united fracture of the radius with unreduced dislocation of the lower end of the ulna—In old injuries when the dislocated lower end of the ulna has been unreduced for many months and there is still inward angulation of the radius with non union the first essential step before attempting replacement and grafting of the radius is to excise one inch of the lower end of the ulna which gives an excellent arthroplasty of the inferior radio-ulnar joint Without preliminary excision of the lower end of the ulna the surgeon is faced with great difficulty in replacing the fragments of the radius whereas if the head of the ulna is first excised the radial fragments can be placed in good position and the results of inferior radio-ulnar arthroplasty are excellent (Figs 934-935)

UNUSUAL FRACTURE-DISLOCATIONS OF THE FOREARM

Dislocation of the upper end of the ulna with fracture of the shaft of the radius—The injury described by Monteggia was a dislocation of the upper end of the radius with fracture of the shaft of the ulna The converse injury is dislocation of the upper end of the ulna with fracture of the shaft of the radius—but so far as I know only one case has been recorded and that was

Fig 944

Fig. 945

Fig 946

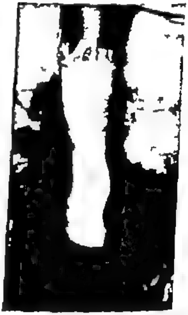

Fig 947

Reduction of Colles fracture of the radius.

The small lower fragment is gripped between the surgeon's thenar eminence and his fingers, and is pushed and tilted forwards (Fig 944); at the same time it is pronated (Fig 945). A new grip is then taken to correct the lateral displacement and the fragment is pushed strongly inwards (Fig 946). After the plaster cast has been applied and while it is setting there should be careful moulding—with the fingers of the left hand the curve of the radial concavity is reproduced in the plaster; with the thenar eminence of the other hand the surgeon pushes the lower fragment and the carpus inwards and forwards.

Fig 930

Fig 931

Fracture of the shaft of the radius with fracture-dislocation of the inferior radio-ulnar joint before and after manipulative reduction. The alignment of the radius was finally adjusted by wedging the plaster

Fig 932

Fig 933

Fracture of the shaft of the radius with dislocation of the inferior radio-ulnar joint before and after operative reduction. Redisplacement was prevented by means of a vitallium screw transfixing the fragments.

After treatment—It is the duty of the surgeon to see that movement is preserved in the finger and thumb joints and in the elbow and shoulder Delay in active exercise of these joints for so short a time as seven or ten

FIG 948

Colles fracture of radius with backward displacement and tilting radial displacement and impaction of the small lower fragment.

FIG 949

Same case after manipulative reduction The articular surface of the radius is now normally directed downwards and forwards.

days may cause such stiffness that full movement may never be regained—or if it is only at the cost of many months of painful treatment As soon as the patient recovers from the anaesthetic three finger exercises and three shoulder exercises should be taught to be repeated hourly throughout the day *Finger exercises*—the fingers are never too swollen to move—indeed

in former editions of this book.[1] There must of course have been other This was an interesting injury sustained by a man aged fifty-seven who fell from a lorry and dislocated his left elbow promptly reducing it by his own manipulation Study of the radiographs taken when he reached hospital leaves no doubt that there had been a valgus strain of the elbow joint with avulsion of the medial epicondyle and backward dislocation of the upper end of the ulna together with a fracture of the shaft of the radius in the lower third (Fig 936) Clearly there had also been rupture of the orbicular ligament and the interosseous membrane so that when the patient pulled the ulna back into contact with the humerus the proximal fragment of th radius remained below its usual position with persistent over riding of th

FIG. 934

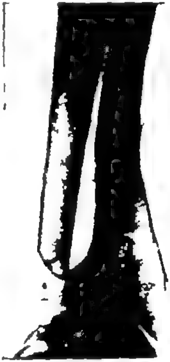

FIG 935

Un united fracture of the lower shaft of the radius with unreduced dislocation of the lower end of the ulna (Fig. 934) treated by excision of the head of the ulna and bone grafting of the radius (Fig. 935).

fragments of the fractured radial shaft It is to the credit of Mr R C. Murra who treated this patient at the Robert Jones and Agnes Hunt Orthopædi Hospital that he reduced it by manipulation without operative exposur though in doing so he had to redislocate the ulna before applying tractio to the limb in the extended position of the elbow Immobilisation wa maintained in the extended position for one month and then in right-angle flexion for two months After seven months recovery was complete wit normal movement of the elbow and radio-ulnar joints

Fracture of the radial head with distal radio-ulnar dislocation—Essex Lopresti fracture-dislocation—Fractures of the head of the radius usuall occur from falls on the outstretched hand which force the elbow into th valgus position and impact the radial head against the capitellum—bu sometimes the upper end of the radius is fractured by longitudinal compressio

[1] See the paragraph on divergent dislocation of the forearm bones at the elbow and isolated dislocation of t upper end of the ulna on page 559

the more swollen they are the more urgent is the need for active exercise 1) the fingers are extended fully and spread into abduction 2) the interphalangeal joints are flexed by touching the palm of the hand with the fingertips 3) the metacarpo-phalangeal joints are flexed to the right angle by reaching with the tips of the fingers towards the front of the wrist special care being taken to see that the index finger is flexed fully and that the position of the thumb does not interfere with the movement *Shoulder exercises*—Three shoulder movements are also to be practised 1) the joint is abducted until the arm is by the side of the head 2) it is rotated laterally by placing the hand behind the neck 3) it is rotated medially by reaching to the shoulder blades with the fingertips *Swelling of the fingers*—The limb should be elevated at intervals in order to prevent swelling It may even be advisable for the patient to remain recumbent with the limb supported on pillows and sometimes to arrange admission to hospital for about forty-eight hours so that elevation of the limb and repeated exercises may be supervised *Duration of immobilisation*—The plaster should not be removed until after five weeks before that time union is not firm enough to prevent redisplacement and moreover removal of the plaster at an earlier date delays recovery of wrist movement rather than encouraging it. If functional activity is maintained by finger exercises the range of movement of the wrist increases steadily even although the joint is immobilised in plaster (see page 43)

Mal-united Colles fracture—After six or eight weeks the difficulties of replacing an unreduced Colles fracture arise more from persistent subluxation of the lower end of the ulna than from backward and outward displacement of the lower end of the radius which is then shortened by resorption of bone In such cases it may be wise to acknowledge that the inferior radio-ulnar joint cannot be restored perfectly and that the best procedure is first to excise the lower end of the ulna and only after that to reduce the radial displacement by manipulation An example of an eight-weeks-old mal united fracture is shown in Figures 950 951 In this elderly doctor's widow who was unwilling to accept either disfigurement or impairment of function, the head of the ulna was excised through a short incision and the lower end of the radius was realigned without much difficulty by firm and strong manipulation the fracture then being treated as if it was a recent injury by immobilisation in a carefully moulded plaster cast The result was excellent both cosmetically and functionally—but let it be noted that manipulative reduction of the displaced radius would have been impossible without first excising the lower end of the ulna

Osteotomy of the radius—When the deformity has persisted still longer it may be impossible to replace the radial fragments by manipulation alone and osteotomy of the radius one inch above the wrist joint is needed—but excision of the subluxated lower end of the ulna is still an essential preliminary The operation described by Jackson Burrows,[1] and later by Willis Campbell [2] in which a fragment of bone was cut from the projecting side of the displaced head of the ulna and implanted into the site of osteotomy so that the distal radial fragment was tilted forwards and inwards

Burrows, H J An Operation for the Correction of Madelung's Deformity and Similar Conditions *Proc Roy Soc Med* (section of Orthopaedics), 1936 30, 565.
Campbell, W C Mal-united Colles Fracture. *J Amer med Ass*, 1937 109, 1105 *Surg Gynec Obstet* 1935 66, 4hh

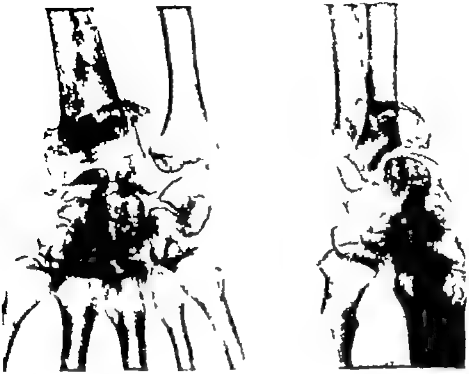

FIG. 630

Colles fracture mal-united after eight weeks in an elderly doctor's widow who resented the deformity and disfigurement just as much as the loss of function. After only eight weeks it is easy to correct displacement by manipulation if the head of the ulna is first excised.

FIG. 631

The displaced fracture of the radius shown in Figure 630 could not have been replaced perfectly without first excising the lower end of the ulna; this was done through a two-inch incision. It was then easy to reduce the radial fracture by manipulation as if it had been a recent fracture and to immobilise it in plaster for five weeks. Perfect symmetry as well as perfect function were thus restored.

Fig 971

Radiographs of wrist the day after a fall on the outstretched hand. There is a fracture of the ulnar styloid process but only a suspicion of injury to the central part of the lower radial epiphysis.

Fig 972

The same wrist two months later There is more definite evidence of abnormality of the central part of the lower radial epiphysis, with early obliteration of a part of the epiphyseal line.

Fig 973

The same wri t six years later showing premature fusion of the lower radial epiphysis. The ulna has continued to grow and has dislocated at the inferior radio ulnar joint. This is not a complication of the ordinary epiphyseal displacement but of crushing of the epiphyseal line Excision of the lower end of the ulna is indicated.

was I think unnecessarily difficult and moreover it failed to relieve the symptoms arising from subluxation of the inferior radio-ulnar joint. It is better to excise all the distal inch of the ulna and not just the prominent part of it. There is then no difficulty in realigning the osteotomised fragments of the radius, and there is no pain or limitation of movement from unreduced radio ulnar subluxation.

Un-united Colles fracture—Non union of a Colles fracture is very rare indeed. One case was reported in the first volume of this book in a fit and healthy man of middle age who had been incapacitated for eight years (p. 333). Another is shown in Figures 952 953 in a stout Canadian woman, aged sixty two whose fracture had been un united for eighteen months. So far as I am aware these are the only two cases of un united Colles fracture that have been reported. Rare as this complication may be it illustrates once again the importance of excising the dislocated lower end of the ulna before

FIG. 952 FIG. 953

Radiograph of un united Colles fracture showing instability of the wrist; Figure 952 is taken with the hand in maximal radial deviation. Figure 953 shows union after excision of the lower end of the ulna and reconstruction of the radius.

trying to realign the displaced or un united distal fragment of the radius. After its excision little difficulty remains in impaling the shaft of the radius into the small distal fragment with perhaps acceleration of union by the transplantation of fragments of cancellous bone from the ilium. It should be mentioned that in both these un united Colles fractures even after excision of the ulna with impaction of the radial fragments and transplantation of cancellous bone immobilisation in above-elbow plaster casts was continued for four months. In such cases there is no liberty to take chances—there must be certainty.

FRACTURE OF THE RADIAL STYLOID PROCESS

Fractures of the base of the radial styloid process are often caused by back fire injuries when the engine of a car is started or sometimes from falls on the outstretched hand. The carpus is thus driven backwards and outwards against the radius but the impact is transmitted mainly by the scaphoid

plaster exactly as for the corresponding fracture in the adult, but there is this important distinction—uncorrected displacement at the lower end of the radius may grow straight in children in a way that uncorrected displacement of Colles fracture cannot grow straight in adults. An example is shown in Figures 967-969: the backward displacement of the lower radial epiphysis was corrected at the time of manipulative reduction but recurred; nevertheless subsequent remodelling restored good alignment.

Crushing of the lower radial epiphysis with premature fusion and arrested growth—In falls on the outstretched hand the wrist is usually in a position of slight dorsiflexion so that the carpus and the lower end of the radius are driven backwards, this being the type of shearing stress that displaces the lower radial epiphysis without damage to the epiphyseal plate or interference with growth. But if the impact occurs when the wrist is fully dorsiflexed with the hand at right angles to the forearm, there is no shearing stress but only a crushing force that damages the disc itself. This injury causes premature fusion of the epiphyseal line with arrested growth of bone[1,2]. At the time of fracture there may be little or no evidence of bone damage, the epiphysis is in its usual position and the possibility of crushing of the epiphysis can be surmised only from the radiographic appearances—but a few months later the signs are more obvious, and after several years there is undoubted evidence of arrested growth of the radius with continued growth of the ulna which therefore dislocates at its lower end (Figs. 971-973).

Fig. 970

Outward and backward displacement of the lower radial epiphysis with greenstick bending of the shaft of the ulna and ulnar paralysis.

Epiphyseodesis of the ulna—If the condition is recognised promptly even before continued growth of the ulna has led to disparity in the length of the bones it might possibly be wise to minimise deformity by operating on the lower ulnar epiphysis: continued growth can be arrested by inserting staples across the epiphyseal line or by drilling in many directions so that it is destroyed. But in these early days it is never easy to be sure how completely the growth of the radius will be arrested and it is nearly always better to wait until the age of eighteen or nineteen years and then to correct the inequality of length by excising the lower end of the ulna.

Excision of the lower end of the ulna—The ulna is exposed subperiosteally so that the attachments of the ligaments of the wrist and radio-ulnar joints are preserved. The bone is resected just above the radio-ulnar joint. The functional and cosmetic results are so excellent that I cannot believe that early epiphyseodesis is wise.

[1] Compere, E. L. "Growth Arrest in the Long Bones." *Amer. med. Ass.*, 1935, 105, 2140.
[2] Aitken, A. P. "Fracture of Distal Radial Epiphysis." *J. Bone Joint Surg.* 1935, 17, 302 and 922.

so that the fracture enters the wrist joint between the scaphoid a lunate bones (Fig 954) Very often there is no displacement of t radial fragment and immobilisation of the wrist in a plaster cast about four weeks is all that is needed but if there is the slight

Fig 954
Fracture of the base of the radial styloid from a back fire injury

Fig 955 Fig 956
Even when there is wide displacement of a fracture of the radial styloid process it can be reduced by manipulation.

placement or irregularity of the articular surface of the joint it must b corrected Just as comminuted fractures of the lower end of the radius ar reduced by direct compression the fragments must be squeezed togethe after traction has been applied the fragments are compressed laterall between the surgeon s two hands Even widely displaced fractures of th radial styloid with dislocation of the joint are thus reduced (Figs 955 956)

FIG 971

Radiographs of wrist the day after a fall on the outstretched hand. There is a fracture of the ulnar styloid process but only a suspicion of injury to the central part of the lower radial epiphysis.

FIG 972

The same wrist two months later There is more definite evidence of abnormality of the central part of the lower radial epiphysis, with early obliteration of a part of the epiphyseal line.

FIG. 973

The same wrist six years later showing premature fusion of the lower radial epiphysis The ulna has continued to grow and has dislocated at the inferior radio ulnar joint. This is not a complication of the ordinary epiphyseal displacement but of crushing of the epiphyseal line. Excision of the lower end of the ulna is indicated.

POSTERIOR MARGINAL FRACTURE OF THE LOWER END OF RADIUS

In this injury a small fragment is chipped from the back of the articular margin of the radius by forcible dorsiflexion of the wrist either as part of a comminuted Colles fracture or as an isolated injury It is often overlooked and may be disclosed only in oblique radiographs (Figs 957 958) but it is important because the floor of the groove in which the tendon of extensor

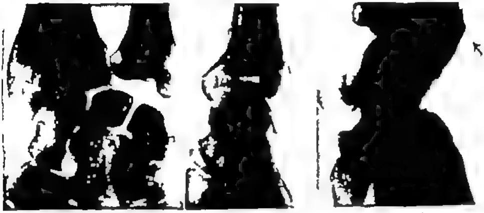

Fig 957 Fig. 958

Posterior marginal fracture of the lower end of the radius. Antero-posterior and lateral radiographs show no evidence of the injury (Fig 957), but it is disclosed by an oblique view (Fig 958). The extensor pollicis longus tendon ruptured spontaneously six weeks later while the patient was rock climbing

Fig 959

Spontaneous rupture of extensor pollicis longus tendon six years after a wrist injury Radiograph (inset) shows an old posterior marginal fracture of the radius.

pollicis longus glides is injured and sharpness of bone fragments or roughening from callus formation may fray the tendon just as a string or rope frays over any sharp margin so that the tendon ruptures spontaneously after several weeks or months or even sometimes after several years (Fig 959). The complication usually occurs in overlooked posterior marginal fractures in which free movement of the wrist as well as movement of the thumb has been allowed from the beginning It is less usual in recognised fractures

FRACTURE OF THE CARPAL SCAPHOID BONE

When a surgeon takes radiographs of the wrist in three planes searches *for a crack in the scaphoid bone with the aid of a magnifying lens* and even then does not accept negative evidence but insists on repeating the X ray examination after several weeks, it might seem that the bounds of reasonable care have been exceeded but all these precautions are essential No fracture is more often overlooked, and no failure of diagnosis is penalised with greater certainty Fractures of the scaphoid never unite spontaneously even in young growing boys and cracks in the bone which may seem trivial and insignificant become un united gap fractures if they are not immobilised complete and uninterruptedly

Clinical and radiographic diagnosis—The fracture may occur from falls on the outstretched hand or from back fire injuries when starting the engine of a car There is slight swelling of the joint in the region of the anatomical snuff box Movements of the wrist are painful and limited and there is tenderness below the radial styloid process The symptoms are often attributed to sprain but simple sprains of the wrist are rare If there is tenderness over the radial side of the joint without obvious deformity a fracture of the carpal scaphoid bone should always be presumed until radiographic examination proves otherwise Radiographs must be taken in three planes Antero-posterior and lateral projections are often less important than oblique projections which show the bone in more accurate profile[1] It may sometimes be difficult to differentiate the line of fracture from normal trabeculation of the bone the crack may appear to be incomplete and to involve only part of the thickness of the bone but it is still a complete fracture and it must not be ignored (Figs. 974-975)

Negative radiographic findings do not always exclude a recent scaphoid fracture—The clinical diagnosis of recent fracture of the scaphoid based on the history and the physical signs of effusion with localised tenderness, is often more accurate than radiographic evidence which is by no means infallible Films of perfect quality taken on the day of injury may show no evidence of the fracture that has been sustained. If clinical features suggest a probable fracture, but antero-posterior and oblique radiographs show no evidence of it the radiographic examination should be repeated two or three weeks later—shearing movement of the fragments has by then destroyed the bone and widened the gap so that after such an interval the fracture is seen quite clearly (Figs 980 981) Only negative radiographic findings several weeks after injury is of certain value in excluding recent fractures of the scaphoid

Diagnosis of recent from old fractures—Recent and old fractures of the carpal scaphoid bone must be distinguished because the age of the fracture has an important bearing on treatment The history given by the patient is often unreliable very often the original injury has been overlooked or forgotten and symptoms arise only after several months or years when a second injury ... ustained A patient with an old fracture often believes that he sustai... only two or three days before (Figs 976-979)

[1] Oraziani, A ... ological Study of the Wrist." *Radiolog. med., Torino* 1940 27 332), suggested that sixteen proj... needed for an exhaustive study of the wrist—dorso-palmar view with the wrist neutral dorsifl...ed and p... flexed palmo-dorsal views, radio-ulnar views and ulno-radial view with the wrist in the same thr... p... two radio-ulnar oblique views and two ulno-radial oblique views.

in which the wrist has been immobilised for several weeks, presumably because the tendon is protected by the limited excursion imposed by immobility of the wrist. Thus although posterior marginal fractures of the radius should always be immobilised for several weeks it is seldom necessary to immobilise the thumb. It usually suffices to discourage early movements of the thumb, concentrating only on exercises of the fingers.

Spontaneous rupture of the extensor pollicis longus.—There may be spontaneous rupture of this tendon even when there has been no fracture, as in the traditional example of the drummer boy whose rapid and repeated

Fig. 960

Fig. 961

Result of transplantation of extensor carpi radialis longus to the distal end of a spontaneously ruptured extensor pollicis longus tendon.

movement is said to cause friction of a normal tendon over a normal bone (though I must admit that I have never seen a drummer boy with such an injury—in fact I have never seen a drummer boy). Usually there is a history of sprain of the wrist with sudden loss of power in the thumb after some months. Careful radiographic examination nearly always shows that the so-called sprain was in fact a posterior marginal articular fracture of the radius involving the groove of the extensor pollicis tendon.[1,2]

Operative treatment.—It is seldom advisable to attempt direct suture of the tendon because the ends are so attenuated that sound repair may be impossible. Even if direct repair succeeds, perhaps with bridging of the gap by nylon sutures as proposed rather surprisingly by Trevor,[3] the tendon

Moore, T.: "Rupture of Extensor Pollicis Tendon in Colles' Fracture." *Brit. J. Surg.*, 1936, 23, 721.
McMaster, P. E.: "Tendon Rupture following Colles' Fracture" (bibliography). *J. Bone Joint Surg.*, 1932, 14, 93.
Trevor, D.: "Rupture of Extensor Pollicis Longus Tendon after Colles' Fracture." *J. Bone Joint Surg.*, 1950, 32-B, 4[illegible]. *J. Bone Joint Surg.*, 1949, 31-B, 4[illegible].

Fig. 974

Fig 975

Few days old fracture of the scaphoid. The crack is much more obvious in the oblique view (Fig. 974) than in the antero-posterior view (Fig 975) The fracture united after six weeks immobilisation.

Fig 976

Fig 977

Few months old fracture of the scaphoid. The decalcification and the cyst formation prove that it is an old injury The fracture united after five months immobilisation (Fig. 977).

Fig. 978

Fig 979

Few years old fracture of the scaphoid. The cystic space has closed but there is sclerosis of the fractured surfaces. The fracture united after drilling and immobilisation for four months (Fig 979). Note the age of the last two patients Fracture of the scaphoid often occurs in young boys.

must then be replaced in the very groove of bone which by its roughening caused rupture Surely it is better to accept one of the many tendon transplants that are so successful The tendons of extensor indicis proprius extensor carpi radialis longus and extensor carpi radialis brevis are all available (Figs 960 961)

Rupture of the flexor pollicis longus—In one patient there was spontaneous rupture of the tendon of flexor pollicis longus three months after a Colles fracture had united with backward displacement Spontaneous rupture of the flexor tendons has also been described from attrition over a thickened lunate bone in Kienbock s disease [1] and in osteoarthritis of the inferior radio ulnar joint [2]

ANTERIOR MARGINAL FRACTURE OF THE RADIUS WITH SUBLUXATION OF THE WRIST

Smith s fracture of the radius or reversed Colles fracture in which there is a fracture through the whole thickness of the lower shaft of the bone similar in type to Colles fracture but with forward instead of backward displacement is an unusual injury (Fig 962) Nearly always when there is forward displacement of the carpus and hand the fracture of the radius

FIG 962

Smith s fracture (or reversed Colles fracture) through the whole thickness of the radius and not extending into the joint—a most unusual injury

extends into the wrist joint and a large anterior marginal fragment is displaced forwards with the carpal bones (Figs 963 964) It is important that the displacement should be reduced accurately because otherwise there will be painful and limited wrist movement After applying traction to the fingers and thumb the marginal fragment should be replaced by compression between the surgeon s hands the displaced anterior marginal fragment of the lower end of the radius being pushed firmly backwards and the wrist joint slightly dorsiflexed over reduction from pressing too strongly is almost impossible A plaster cast is applied and while it is setting pressure should again be maintained over the front of the lower end of the radius and carpus Immobilisation in plaster should be continued for five weeks

[1] James, J I P Ruptur of the Flexor Tendons Secondary to Kienbock Disease." J Bone Joint Surg. 1949 31 B, 521

[2] Vaughan-Jackson O J Rupture of Extensor Tendons by Attrition at the Inferior Radio-ulnar Joint." J Bone Joint Surg 1948 30-B 528

Recent fractures of the scaphoid are nearly always fine cracks if there is cystic change between the fragments the fracture is not less than six weeks old and if the gap is partly filled, with dense sclerosis of the fractured surfaces the injury is not less than one year old

FIG. 980

The clinical signs suggested a probable fracture of the scaphoid, but careful examination of the X ray films, even with a magnifying lens, failed to show evidence of bone injury

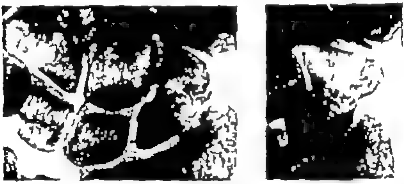

FIG. 981

Radiographs taken three weeks later show the fracture very clearly This occurs far too often for there to be any doubt that the fracture was actually present at the time of injury three weeks earlier

Differentiation of old fractures from congenitally bipartite scaphoid—Old un united fractures of the scaphoid with smooth and rounded fragments must be distinguished from congenitally bipartite scaphoids—a distinction that is often difficult There are three types of developmental anomaly separation of an os centrale which is the most frequent (Figs 982 983), separation of an os radiale externum corresponding to the os tibiale externum of the tarsus and equal division into a bipartite bone divided across the waist It is the last type that is most difficult to distinguish from un united fracture and may have important medico-legal significance The literature is confusing because many cases reported as bipartite scaphoids were almost certainly un united fractures [1 7] It has often been assumed that separation of a fragment from the scaphoid must be of congenital origin if the patient

Boyd, G I Bipartite Carpal Navicular Bone *Brit. J Surg.*, 1932-33 20, 455.
Ogilvie, W H Howell B W Aitken, D McC and Irwin, S T "Bipartite Scaphoids. *Proc. Roy. Soc Med* 1930 24, 40
Lachapelle, *Soc. de Radiol Med. de France* 1930 18, 162.
Bipartite Scaphoid *J Bone Joint Surg.*, April 1943.
Pfitzner *Zeits f Morph u. Anthrop* 1900, 2, 77 365.
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Johnson H M. *J Anat.*, 1906 41 64.

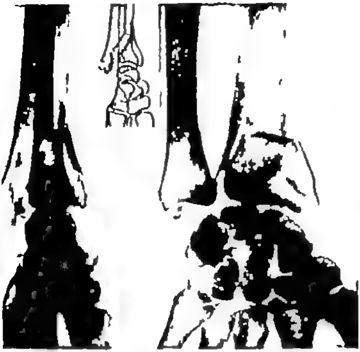

Fig 603

Fig 604

Anterior marginal fracture of the radius with forward displacement of the carpus and hand before and after manipulation reduction. The marginal fragment must be pressed very strongly backwards in order to restore a smooth joint surface. It cannot be over-reduced by compression between the surgeon's hands because the fragment locks in position. While the plaster is setting strong pressure should be maintained over the front of the wrist and the displaced marginal fragment with the joint in a moderate degree of flexion.

remembers no injury and if the other wrist joint shows similar changes—but both these assumptions are wrong Many patients cannot recall the injury that first caused a fracture and bilateral scaphoid fractures from one injury or from two successive injuries are not at all uncommon It is usually

Fig 982

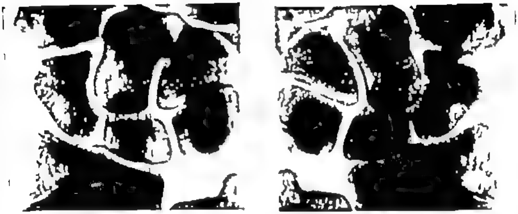

Fig 983

Oblique and lateral radiographs of both wrist joints in a patient with bilateral os centrale. Other members of the family had normal scaphoids.

possible to establish the distinction by noting the texture of the bone if separation arises from developmental anomaly each fragment has a normal blood supply and there is no evidence of avascular necrosis but if the line of demarcation is irregular and the bone texture is abnormal with patches of sclerosis indicating avascular necrosis the separation has almost certainly arisen from fracture whether or not the patient remembers an injury and whether the lesion is unilateral or bilateral

Three anatomical types of fracture of the scaphoid—The bone may be fractured at any of three levels—the tubercle, the waist, or the proximal pole The most common injury is a fracture of the waist. Fractures of the tubercle and of the proximal pole are more rare The difference in behaviour of these three types of fracture is explained by variations in the blood supply of the bone which were discussed in the first volume on page 86 *Fractures of the tubercle*—The fracture is entirely extra articular, both fragments have a free blood supply and union is certain and rapid whether the wrist is immobilised or not It is advisable to protect the joint by a plaster cast

INJURIES OF THE LOWER RADIAL EPIPHYSIS

Two types of injury to the lower radial epiphysis should be differentiated The ordinary fall on the outstretched hand which in adults causes a Colles fracture may similarly displace the lower radial epiphysis in children This is a fracture through the metaphysis which does not crush epiphyseal cells or cause arrested growth of the radius On the other hand a fall on the wrist joint in more full dorsiflexion may compress and crush the epiphysis without displacing it—a much more serious injury

Displacement of the lower radial epiphysis—A child who falls on the outstretched hand seldom sustains a greenstick Colles fracture of the radius more often the lower radial epiphysis is displaced backwards Epiphyseal separations are essentially fractures adjacent to the epiphyseal disc and not fractures through the disc the line of cleavage being on the metaphyseal side of the epiphyseal plate so that cartilage cells are undamaged and the injury does not cause arrested growth. The displaced epiphysis always carries with it a fragment from the margin of the metaphysis over which the epiphysis is displaced [1] If it is a simple backward displacement of the epiphysis a triangular fragment is detached from the back of the metaphysis and if there is both backward and outward displacement a fragment is detached from the postero-lateral aspect of the metaphysis (Fig 965) No matter how slight the degree of epiphyseal displacement there is always injury to the margin of the metaphysis and in fact minor epiphyseal separations are often disclosed more clearly by greenstick buckling of the back of the metaphysis than by obvious displacement of the epiphysis

Fig 965
Displacement of lower radial epiphysis showing the marginal fragment detached from the metaphysis with greenstick fracture of the ulna.

Remodelling after imperfect replacement—Backward displacement without serious tilting often grows straight despite imperfect reduction (Figs 966-969) It is of course better to be sure and to correct the displacement

Manipulative reduction—As the epiphysis of the radius is driven from the shaft there must be corresponding injury to the ulna with avulsion of the styloid process or displacement of the lower ulnar epiphysis or even greenstick bending of the lower shaft of the ulna which in one case caused ulnar paralysis from stretching of the nerve over the displaced metaphysis of the radius (Fig 970) [2] The displacement is reduced by the same manipulation as that used for Colles fracture of the radius but it is of course still more easy because the fragments lock so securely that over reduction is virtually impossible—all that is needed is to press the epiphysis strongly forwards and inwards After reduction the limb should be immobilised in

[1] Holland [illegible] Thurstan [illegible] Radiographic Note on Injuries to the Distal Epiphyses of the Radius and Ulna. *Proc. Roy. Soc. Med.* ([illegible] Electro-Therapeutics) 1929 **22**, 695
[2] W[illegible] [illegible] —Displacement of the Radial Diaphysis *J. Bone Joint Surg* [illegible] 12, [illegible]

Recent fractures of the scaphoid are nearly always fine cracks, if there is cystic change between the fragments the fracture is not less than six weeks old and if the gap is partly filled, with dense sclerosis of the fractured surfaces, the injury is not less than one year old

FIG. 980

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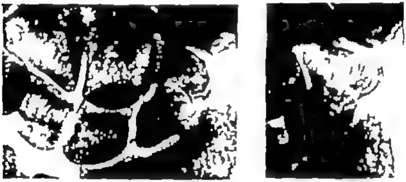

FIG. 981

Radiographs taken three weeks later show the fracture very clearly This occurs far too often for there to be any doubt that the fracture was actually present at the time of injury three weeks earlier

Differentiation of old fractures from congenitally bipartite scaphoid—Old un united fractures of the scaphoid with smooth and rounded fragments must be distinguished from congenitally bipartite scaphoids—a distinction that is often difficult There are three types of developmental anomaly separation of an os centrale which is the most frequent (Figs 982 983) separation of an os radiale externum corresponding to the os tibiale externum of the tarsus and equal division into a bipartite bone divided across the waist It is the last type that is most difficult to distinguish from un united fracture and may have important medico-legal significance The literature is confusing because many cases reported as bipartite scaphoids were almost certainly un united fractures [1 7] It has often been assumed that separation of a fragment from the scaphoid must be of congenital origin if the patient

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Hardman, T G. and Wigoder, S. B. *Brit. J Radiol.*, 1928 1 155.
Johnson, H. M. *J Anat.* 1906, 41, 64.

Fig. 966

Fig. 967

Fig. 968

Fig. 969

Backward displacement of the lower radial epiphysis (Fig. 966) It was almost completely corrected (Fig. 967) but displacement recurred (Fig. 968); nevertheless alignment was restored in this growing child by later remodelling with resorption of the projecting anterior margin of the radial metaphysis (Fig. 969).

remembers no injury and if the other wrist joint shows similar changes—but both these assumptions are wrong Many patients cannot recall the injury that first caused a fracture, and bilateral scaphoid fractures from one injury or from two successive injuries are not at all uncommon It is usually

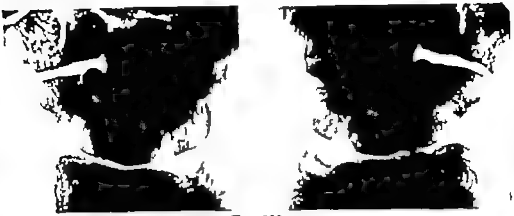

FIG 982

FIG 983

Oblique and lateral radiographs of both wrist joints in a patient with bilateral os centrale. Other members of the family had normal scaphoids.

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plaster exactly as for the corresponding fracture in the adult but there is this important distinction—uncorrected displacement at the lower end of the radius may grow straight in children in a way that uncorrected displacement of Colles fracture cannot grow straight in adults An example is shown in Figures 967 969 the backward displacement of the lower radial epiphysis was corrected at the time of manipulative reduction but recurred nevertheless subsequent remodelling restored good alignment

Crushing of the lower radial epiphysis with premature fusion and arrested growth—In falls on the outstretched hand the wrist is usually in a position of slight dorsiflexion so that the carpus and the lower end of the radius are driven backwards this being the type of shearing stress that displaces the lower radial epiphysis without damage to the epiphyseal plate or interference with growth But if the impact occurs when the wrist is fully dorsiflexed, with the hand at right angles to the forearm, there is no shearing stress but only a crushing force that damages the disc itself This injury causes premature fusion of the epiphyseal line with arrested growth of bone [1 2] At the time of fracture there may be little or no evidence of bone damage the epiphysis is in its usual position and the possibility of crushing of the epiphysis can be surmised only from the radiographic appearances—but a few months later the signs are more obvious and after several years there is undoubted evidence of arrested growth of the radius with continued growth of the ulna which therefore dislocates at its lower end (Figs 971 973)

Fig 970
Outward and backward displacement of the lower radial epiphysis with greenstick bending of the shaft of the ulna and ulnar paralysis.

Epiphyseodesis of the ulna—If the condition is recognised promptly even before continued growth of the ulna has led to disparity in the length of the bones it might possibly be wise to minimise deformity by operating on the lower ulnar epiphysis continued growth can be arrested by inserting staples across the epiphyseal line or by drilling in many directions so that it is destroyed But in these early days it is never easy to be sure how completely the growth of the radius will be arrested and it is nearly always better to wait until the age of eighteen or nineteen years and then to correct the inequality of length by excising the lower end of the ulna

Excision of the lower end of the ulna—The ulna is exposed subperiosteally so that the attachments of the ligaments of the wrist and radio-ulnar joints are preserved The bone is resected just above the radio-ulnar joint The functional and cosmetic results are so excellent that I cannot believe that early epiphyseodesis is wise

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Aitken, A. P Fracture of Distal Radial Epiphysis." *J Bone Joint Surg.*, 1935, 17 302 and 922.

which may be discarded after two or three weeks *Fractures of the waist*—As a rule both fragments have a free blood supply but the fracture is intra articular, there is no natural fixation and union is secured only if the wrist joint is completely immobilised in plaster If the fracture is recent it usually unites within eight or ten weeks, but immobilisation must be continued until there is radiographic evidence of union *Fractures of the proximal pole*—About two-thirds of fractures of the proximal pole are similar to fractures of the waist—each fragment has a free blood supply and if the joint is immobilised suitably, repair is usually complete within about eight weeks In one-third of proximal pole fractures there may be

FIG 984

Bilateral fracture of the scaphoids showing the type of plaster cast used. It extends to the metacarpal heads and includes the whole of the first metacarpal. The hand is tightly gripped so that there cannot be any trace of wrist movement, but the plaster in the palm does not extend beyond the transverse skin creases.

impairment of blood supply of the small fragment with slow repair and prolonged immobilisation is then needed

Treatment of recent fractures of the scaphoid—Fractures of the carpal scaphoid bone must be immobilised rigidly and without interruption until union is sound The scaphoid occupies a position midway between the proximal and distal rows of the carpus and the usual line of fracture is through the waist of the bone in the plane of the mid-carpal joint so that there is a susceptibility to shearing stress which is not compensated in this fracture as it is in so many others by subperiosteal bone formation because of course there is no periosteum round the scaphoid. The support of a cock up splint is useless A plaster cast must be applied from the metacarpals to just below the elbow moulded closely to the palm of the hand as far as the distal skin crease and including the metacarpal bone of the thumb (Fig 984) or perhaps still better the metacarpo-phalangeal joint

and proximal phalanx The position of immobilisation should be that of t clenched fist with the wrist slightly dorsiflexed and the thumb in the oppos position in line with the forearm The thumb should not be abducted *

Complete and rigid immobilisation of the wrist joint and base of the thum must be continued until there is certain evidence of union of the fractur bone : This usually takes from eight to ten weeks, but it may take from eig to ten months, and it is quite wrong to try to determine in advance t number of weeks or months that may be needed In former years it w thought that three weeks was enough some surgeons then suggested s weeks or eight weeks or perhaps even ten weeks but the fact is that : dictate of a calendar should be accepted Nearly all fractures of this bo unite if the period of immobilisation is suitably prolonged and the fi principle to be observed is that immobilisation in plaster should be continu without interruption for as long as may be needed until union is sound

FIG 985

FIG. 986

FIG 987

This patient had a fracture of the carpal scaphoid bone with delayed union (Fig 985) It was immobilised in plaster for three months and radiographs after that time were thought to show sound union (Fig 986). No oblique view was taken, and no arrangements were made for repeated examination three or four weeks after discarding the plaster Thus it was not until two years later that unsoundness of union was recognised (Fig. 987).

Tests for union of fractures of the carpal scaphoid bone—How can it decided that union is sound and that the plaster may be discarded ? clinical test can be relied upon and we must always depend on radiograp evidence In interpreting this evidence the same caution should be exercis as was done earlier in establishing the diagnosis Union is firm and s only when radiographs show obliteration of the line of fracture in obliq as well as antero posterior and lateral views confirmed by X ray examinat repeated after an interval of three or four weeks If immobilisation interrupted before union is sound shearing movement causes resorption the young and immature bone and the fracture reverts first to the cy stage of delayed union and then to that of established non union w sclerosis (Figs 985-987)

Summary of the treatment of recent fractures of the scaphoid—Thus

* A surprising observation was made recently by a surgeon who said that a patient with bilateral fractur the scaphoid needed the whole-time service of an attendant because he could not even deal with ordi toilet. This surgeon was obviously applying plaster casts with the thumb in wide abduction—a functio useless position. Immobilisation of the wrist joint is sometimes needed for many months, and functi activity must be continued throughout such time There is no need at all to abduct the thumb. It sh be immobilised in plaster in such a position that the finger tips can reach the thumb—that is to say in opposi

Perilunar dislocation of the carpus—The lunate may remain in normal relationship with the radius while there is perilunar dislocation of the carpus in a backward and radial direction (Fig 1014) In recent cases it is seldom

Fig 1015

Fig 1016

Trans-scapho-perilunar dislocation of the carpus

The lunate and proximal half of the scaphoid are in normal position, but the rest of the carpus is displaced backwards and radially (Fig 1015). In this case there happens to be also a fracture of the radial styloid process. The displacement is reduced by traction with pressure on the carpus forwards and inwards and after immobilisation for several months the fracture of the scaphoid unites (Fig 1016)

difficult to correct the displacement by first applying traction and then pushing the carpus forwards and medially The joint should be immobilised in plaster in a flexed position for one week and then in the neutral position

ligament may arise after recent fractures of the scaphoid. Figure 996 shows the wrist joint of a distinguished musician. As well as the fracture of the carpal scaphoid there was a fracture of the cuneiform and it was in fact a trans-scapho-perilunar trans-cuneiform fracture subluxation of the joint. Within forty-eight hours he developed excruciating pain in the median distribution of the hand with impairment of touch sensation and evidence of incomplete median paralysis. As an emergency procedure the anterior carpal ligament was divided. The symptoms were relieved at once. It was

FIG. 996

Recent fracture of the carpal scaphoid with acute median nerve compression. Study of the films show that there was also a fracture of the cuneiform (it was, in fact, a trans-scapho-perilunar trans-cuneiform fracture-subluxation). Within forty-eight hours there was agonising pain in the median nerve distribution with paralysis which was relieved promptly by division of the anterior carpal ligament. The nerve had been compressed by hemorrhage and effusion within the carpal tunnel. The patient was a distinguished violinist—and the injury was to his left hand; but he is now leading his orchestra once again.

nearly four months before recovery from the median palsy was complete but after that he resumed duty as the leader of his orchestra.

Tardy median palsy after old fracture of the scaphoid—Median neuritis is very rare indeed in recent fractures of the scaphoid but after many years of non-union with secondary arthritis and the formation of osteophytes which crowd the carpal tunnel with new bone formation paralysis of the median nerve arises not uncommonly. Indeed the first evidence of compression of the nerve may arise as long as twenty years after fracture (Figs. 997, 998). Such cases have been reported by Zachary[1] Cannon and

[1] Zachary, R. B. "Thenar Palsy due to Compression of the Median Nerve in the Carpal Tunnel." *Surg. Gynec. Obstet.* 1945, 81, 213.

or very slight dorsiflexion for another two or three weeks In old unreduced cases operative reduction may be needed and it is reassuring to know that since the ligaments of the lunate itself are relatively uninjured there is minimal loss of blood supply and avascular necrosis with degenerative arthritis seldom arises

Dislocation of the lunate and half-scaphoid, and trans-scapho-perilunar dislocation of the carpus—The commonest fracture dislocation of the wrist is backward and radial displacement of the carpus from the lunate and half scaphoid.[1] *There is a fracture through the waist of the scaphoid bone* the proximal half of the scaphoid together with the lunate remaining in normal relationship to the radius while all the other carpal bones are displaced backwards and medially This is essentially the same injury as perilunar dislocation of the carpus except that the proximal half of the scaphoid stays with the lunate Moreover the treatment is the same except that after reduction of the displacement immobilisation in plaster must continue long enough to gain union of the fractured scaphoid. As before the displacement is to be reduced by applying traction to the wrist and pressing the carpal bones forwards and to the ulnar side then immobilising the joint in plaster first in the flexed position then in the neutral position and after a few weeks in a slightly dorsiflexed position for as many months as may be needed for union of the fractured scaphoid (Figs 1015 1016) In a fairly large series of cases recently reviewed the necessary period of immobilisation averaged no less than five months

The treatment of old unreduced trans scapho-perilunar dislocations of the carpus is just the same as has already been outlined in perilunar dislocations There is also exact similarity in that trans scapho-perilunar carpal dislocation has its counterpart in forward dislocation of the lunate and half scaphoid which in recent injuries can usually be reduced by manipulation but in old injuries may sometimes need excision of the displaced bones

Unusual injuries of the carpus—Subluxations and dislocations of every single one of the carpal bones have been reported Furthermore chip fractures which are not of any particular significance are quite common [2,3]—they need only protection in a dorsal plaster cast for two or three weeks. Dislocations of the trapezium trapezoid [4] or hamate [5,6] are more important because they sometimes need open reduction

Russell, T B. "Intercarpal Dislocations and Fracture-dislocations." *J Bone Joint Surg.*, 1949, 31 B, 524.
Greening, W P *Brit. med. J* 1953, 1, 221
Fairbank, T J *Brit. med. J* 1942, 2, 310
Russell, T B *J Bone Joint Surg.*, 1949 30-B, 530.
Johansson, S Dislocation of Os Hamatum. *Acta radiol., Stockh.*, 1926, 7 9.
Geist, D C "Dislocation of Hamate (Unciform) Bone." *J Bone Joint Surg* 1930 21 215.

FIG. 907

FIG. 908

Twenty years old un-united fracture of the carpal scaphoid bone in which secondary arthritis with osteophyte formation caused crowding and compression within the carpal tunnel so that tardy median palsy developed (Fig. 907). Note at operation when the anterior carpal ligament was divided how seriously the trunk of the median nerve was compressed (Fig. 908). Division of the ligament was all that was needed to cure the median paralysis. *(Photograph by M. Ruddick at the Orthopaedic and Accident Department of the London Hospital.)*

CHAPTER XXIII

INJURIES OF THE FINGERS AND HAND

Fractures of phalanges and dislocations of interphalangeal joints have often been regarded as trivial injuries and been neglected whereas the fact is that stiffness of even one finger from minor injury may be more disabling than major fracture of the shoulder joint or elbow—and economically it may be far more serious If the hand is crippled the whole limb is crippled Such injuries must be treated with especial care Let us first outline the principles of treatment

The injured finger should be supported and protected—Stiffness of an injured finger cannot be prevented by immediate vigorous exercise without suitable support Movement is restored more rapidly if the torn structures are protected for ten or fourteen days until the traumatic reaction has subsided Moreover the relief from pain gained by immobilisation of an injured finger encourages the patient to move the other fingers so that stiffness of the rest of the hand is then avoided

The injured finger should be immobilised in flexion—The practice of strapping an injured finger to a wooden spatula or straight metal splint is harmful This position of immobilisation with the joints fully extended often increases the displacement of fractures and always makes it difficult to regain flexion movement Furthermore if one digit is held extended it is almost impossible to flex the others so that they too may become stiff There is no fracture or dislocation of a finger that needs immobilisation with all three joints in the position of full extension

No finger except the injured one should be immobilised—Every uninjured finger should be left free from splints, strapping and bandage To fix the hand on a flat piece of wood or to bandage all the fingers over a pad of wool in the palm is the worst treatment Splints and strapping should be applied in such a way that they do not obstruct movement of the uninjured fingers The urge to cover everything with a neat and tidy bandage must be resisted

Every uninjured finger should be exercised actively—It is not enough to be sure that uninjured fingers are left free to move—it is the surgeon's duty to see that they are in fact moved Every joint should be exercised actively throughout its normal range many times a day To waggle a finger in the middle range of movement is futile the limits of flexion and extension movement must be reached

Passive stretching must be avoided—It is never easy to resist the temptation to help a patient by pushing and forcing a finger that is becoming stiff Every time that this is done the joint becomes more stiff Forcible passive movement is one of the certain causes of permanent stiffness The patient should be encouraged in the practice of his own exercises but movement is not to be forced or assisted in any other way Manipulation of a stiff finger under anaesthesia is seldom advisable

Swelling should be controlled by elevation of the limb—If the fingers are

Love[1] Newman[2] and in other fractures near the wrist joint[3-4] In such injuries complete relief is gained by division or excision of the transverse carpal ligament It should be noted that median paralysis may also arise from carpal tunnel compression even when there has been no fracture (Brain and Wright)[5] and sometimes when the carpal ligament is thickened as in acromegaly (Woltman)[6] or pleonosteosis (Watson-Jones)[7]

DISLOCATION OF THE CARPAL SCAPHOID BONE

Although fractures of the carpal scaphoid bone are so well known subluxations and dislocations have passed almost unrecognised[8-11] The fact is that even complete dislocations are not very rare and minor subluxations in association with other carpal injuries are quite common An example of subluxation of the scaphoid with dislocation of the lunate is shown in Figure 1013 Sometimes there is even greater rotational displacement As a rule the proximal pole of the scaphoid is tilted backwards and the distal part of the bone is tilted forwards Five such injuries were seen in the Royal Air Force Orthopædic Service during the recent war As a rule the displacement can be corrected by applying traction with direct pressure over the proximal pole of the bone the wrist then being supported in moderate dorsiflexion and radial deviation Sometimes however, the scaphoid may be locked over the back of the radial styloid process and operative reduction is needed In other cases manipulative reduction may be prevented by the interposition of a capsular flap from the back of the joint which lies between the scaphoid and lunate and this must be removed before manipulation can succeed (Figs 999 1000)

Recurrent dislocation of the carpal scaphoid—If dislocation of the scaphoid bone from a first injury is not reduced and immobilised recurrent subluxation or dislocation may arise Of the several cases of recurrent dislocation that have been recognised the clearest example is the one recorded by my colleague Vaughan-Jackson[12] This was a patient, aged thirty-one years who injured his wrist joint while playing Rugby football In later years he could readily dislocate or replace the bone by his own active effort The typical movement that caused displacement was the throwing of a dart with a sudden jerk of the wrist in the direction of palmar flexion but he could always replace the bone just as readily and for this reason declined operative treatment (Figs 1001 1002) In two other patients with recurrent dislocation of the scaphoid I have operated and reefed the capsule over the back of the proximal pole of the bone just as the capsule is reefed over the front of the shoulder joint in recurrent forward dislocation with complete relief of symptoms

Cannon, B. W and Love, J G "Tardy Median Palsy Median Neuritis Median Thenar Neuritis Amenable to Surgery" Surgery 1946, 20, 210
Newman I H "Median Nerve Compression in the Carpal Tunnel" Post-grad. med J 1948, 24, 264.
Paget, Sir James "Lectures on Surgical Pathology" (median palsy from fracture of the lower end of the radius) p 31 London Longmans Green, Longmans, Robert & Green, 1863
Lewis, D and Miller E. M "Peripheral Nerve Injuries in Association with Fractures." Trans. Amer Surg Ass 1922, 40, 489
Brain, W R, Wright, A D and Wilkinson, M "Spontaneous Compression of both Median Nerves in the Carpal Tunnel—Six Cases treated Surgically" Lancet, 1947 1 277
Woltman, H "Neuritis associated with Acromegaly" Arch. Neurol. Psychiat., 1941, 45, 680.
Watson-Jones R. "Leri Pleonosteosis, Carpal Tunnel Compression of the Median Nerves, and Morton's Metatarsalgia (with bibliography)" J Bone Joint Surg 1949 31-B, 560.
Watson-Jones R "Dislocation of Scaphoid." Proc. Roy Soc Med 1929, 22, 1064
Schnek F "Carpal Dislocations" Ergebn. Chir Orthop., 1930 23, 1
Buzby, B F "Isolated Radial Dislocation of Carpal Scaphoid." Ann. Surg 1934 100, 553.
Woodd Walker G B "Dislocation of the Carpal Scaphoid." Brit. J Surg 1943, 30, 380.
Vaughan-Jackson O J "Recurrent Subluxation of the Carpal Scaphoid." J Bone Joint Surg 1949, 31-B, 532.

swollen the danger of stiffness is greatly increased. Even a finger that has not been injured becomes stiff very quickly if it shares in reactionary œdema and is not exercised regularly. The limb should be elevated so that gravity aids and does not hinder the dispersal of swelling. It is usually wise for the patient to rest in bed for a few days with pillows so arranged that the hand is above the level of the heart.

Fractures of the phalanges should be reduced accurately—If a fractured shaft of a phalanx unites with forward angulation, flexion movement of the finger will be limited by a corresponding degree—but there will also be limitation of movement from adhesion of the flexor tendons in the tunnel of which the phalanx is the floor and which is encroached upon by displaced bone fragments or masses of callus. If stiffness of the finger is to be prevented fractures of the phalanges must be reduced accurately.

Fig. 101

Amputation of the thumb for un-united fracture of the phalanx can be described only as a disaster. Radical measures such as this have no place in the surgery of the thumb.

The importance of momentary subluxation of the interphalangeal joints should be recognised—It has long been known that apparently simple strains of finger joints may cause surprisingly long periods of disability, sometimes lasting for many months. These so-called sprains have usually been momentary dislocations with tearing of capsule or avulsion of marginal fragments of bone. If they are treated as spontaneously reduced dislocations by immobilisation for two or three weeks and then by active exercise without passive stretching recovery is usually complete within three to six months.

Open fractures of the phalanges should be treated by prompt excision of the wound—Open fractures of the phalanges may present even greater difficulty than open fractures of the femur and from an industrial point of view the results of treatment are even more important. The wound should be excised with all the precautions of aseptic technique.[1,2] There is seldom need to excise the skin margin. Raised flaps of skin with undamaged blood supply should be replaced. Cut tendons and digital nerves should not be sutured unless the wound is cleanly incised and not contaminated—it is usually better to arrange delayed suture after the wound is healed. In incised wounds from sharp instruments or glass the

Koch, S. L. Injuries of the Hand. J. Amer. med. Ass., 1936, 107, 1044.
Bunnell, S. Injuries of the Hand. J. Amer. med. Ass. 1936 107 1044.

Fig. 999

Fig. 1000

Dislocation of the carpal scaphoid bone. The proximal pole is displaced over the radial styloid process (Fig. 999). It can usually be reduced by manipulation, but an interposed curtain of capsule may make operative reduction necessary. (This case was treated successfully by Mr J. N. Wilson at the Robert Jones and Agnes Hunt Hospital.)

Fig. 1001

Fig. 1002

Recurrent dislocation of the carpal scaphoid bone. As with other dislocations, if the first injury is not suitably immobilised the dislocation will recur. In this patient, who was seen at the London Hospital and recorded by Vaughan-Jackson, the bone dislocated every time he threw a dart. The disability can be relieved by capsular reefing behind the proximal pole of the bone. (*By permission of the "Journal of Bone and Joint Surgery" 1949, 31 B, 53.*)

wound may be sutured but in other circumstances it is better just to cover it with gauze and bandage If skin has been destroyed it should be replaced promptly by free split skin grafts, or sometimes by pedicle flaps from the abdomen [1]

The occasional need for prompt amputation of a finger should be recognised—In adults a severely crushed finger which will be permanently stiff should be amputated early rather than late especially if there is infection After injuries of this type the injured finger is often the least important part of the final disability Stiffness of the other fingers from continued infection, which could have been avoided by early amputation of the injured digit is often the greatest incapacity In children however the tendency to permanent joint stiffness is so much less that there is greater justification for conservative treatment

The thumb should seldom be amputated—Radical treatment by early amputation should not be used for injuries of the thumb which is the equivalent of almost half the hand Even a rigid stump of the thumb the skin of which has been replaced by grafting is better than no thumb at all [2] It is indeed difficult to over-emphasise the importance of avoiding amputation of the thumb it should never be considered except as a last resort The case shown in Figure 1017 where the thumb was amputated for an un united fracture of the proximal phalanx can be described only as a disaster

FRACTURES OF THE BASE OF THE THUMB METACARPAL

Whereas Colles fracture of the radius usually occurs in women 90 per cent of metacarpal fractures are in men the commonest site being the base of the thumb metacarpal In a study of 1 200 fractures of the hand by my colleague Norman Roberts at the Liverpool Royal Infirmary [3] it was found that of 700 fractures of the metacarpals there were 173 at the base of the thumb 145 in the shafts of the fourth and fifth metacarpals and 120 through the neck of the fifth metacarpal the rest of the fractures being distributed in much smaller groups in the necks shafts and bases of other metacarpal bones

Fractures at the base of the thumb from direct blows are often sustained by amateur and professional boxers Of these two types of injury should be differentiated, because although the mechanism of injury and the clinical signs are the same the method of treatment and the prognosis are quite different 1) fracture of the base of the thumb metacarpal not involving the joint 2) fracture-dislocation involving the carpo-metacarpal joint usually known as Bennett s fracture

Fracture of base of thumb metacarpal not involving the joint—The fracture lies within half an inch of the joint but there is no joint injury The fragments are angulated outwards and backwards and they are impacted on the inner side (Figs 1018 1019) After reduction of the displacement by applying traction to the thumb with firm pressure over the base of the metacarpal the position of the fragments is stable and there is little or no difficulty in preventing redisplacement A plaster cast is applied to the forearm and hand with the thumb abducted and the metacarpo-phalangeal joint slightly flexed the terminal joint should be left free for active exercise

[1] Evans E Mervyn "Treatment of Major Injuries of the Hand" Brit J Plastic Surg 1949 2, 1[illegible]
[2] Brown J B "Repair of Surface Defects of the Hand" Ann Surg 193[illegible] 107 9[illegible]
[3] Roberts N W "Fractures of Phalanges & Metacarpals" Proc Roy Soc Med (Section Orthop.) 1938 31 793.

DISLOCATION OF THE LUNATE AND PERILUNAR DISLOCATION OF THE CARPUS

The variety of dislocations and fracture-dislocations of the carpus is almost infinite Any carpal bone may be dislocated forwards or else the rest of the carpus may be dislocated backwards from one bone which remains in normal position The simplest example is dislocation of the lunate From a fall on the outstretched hand this bone may be tilted forwards so that its cup lies in front of the head of the capitate which should receive it the only bone that is displaced is the lunate itself (Fig 1003) On the other hand the lunate may remain in normal position in relation to the radius

Fig 1003

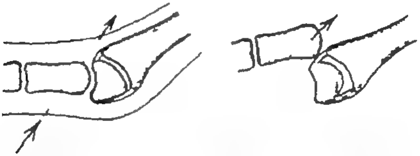

Fig 1004

According to the direction of the blow a fall on the outstretched hand produces either a forward dislocation of the lunate (Fig 1003) or a backward dislocation of the capitate (perilunar dislocation of the carpus (Fig. 1004))

while the rest of the carpus is dislocated backwards from it—perilunar dislocation of the carpus (Fig 1004) Thus we see the converse injuries of forward dislocation of the lunate or backward perilunar dislocation of the carpus

In the same way when the scaphoid is fractured in association with rupture of the ligaments of the lunate there may be forward dislocation of the lunate and half scaphoid or alternatively backward trans-scapho-perilunar dislocation of the carpus Similarly, the lunate together with the whole of the scaphoid may be dislocated forwards—or there may be peri-scapho lunar dislocation backwards There is sometimes dislocation of the lunate with the triquetral—or alternatively peri triquetro-lunar dislocation of the carpus The hamate may be dislocated or the trapezium

The treatment of this fracture is in marked contrast with that of Bennett' fracture-dislocation where reduction is unstable and the penalty of imperfe reduction is usually a painful and stiff joint

Fig 1018

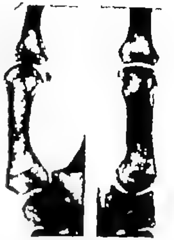

Fig 1019

A fracture of the base of the first metacarpal not involving the joint is easy to treat. All that is needed is manipulative reduction by traction with abduction and then immobilisation in a simple plaster

Bennett's fracture-dislocation of the thumb[1]—Bennett's fractur dislocation is a more serious injury and treatment is often difficult Th fracture extends through the base of the thumb metacarpal into the carp metacarpal joint and separates a triangular fragment from the medial sid But the fractured marginal fragment is the least important part of th injury this is not really displaced—it is the metacarpal itself that i displaced and subluxated from the trapezium (Figs 1020 1021) Th articular surface of the trapezium is saddle-shaped and the fracture enter the joint opposite the top of the saddle so that whereas the small fragmen stays in normal position on one side nothing stops the metacarpal fro sliding down the other the tension of flexor and extensor tendons pulling i down the sloping surface Thus reduction of a Bennett s fracture-dislocatio of the thumb is usually unstable[2,4]

Treatment—The dislocation can be reduced by traction applied to th thumb with pressure over the base of the metacarpal While traction i maintained a plaster cast is applied and moulded closely to the base of th thumb and radial side of the carpus Some surgeons have found it possibl to prevent redisplacement by moulding the plaster carefully over the bas of the metacarpal bone and applying a new plaster when the first cast get loose but I have preferred to add the safety measure of skin traction fo

[1] Edward Hallaran Bennett was born in Cork in 1837 and died in Dublin at the age of seventy He m received his medical training at Trinity College he was the first graduate to be awarded the new degree o M.Ch. At the age of thirty-six he was appointed professor of surgery As curator of the *Pathological Museu* he arranged and catalogued a remarkable collection of fractures, dislocations and diseases of bone Th paper in which he described the *fracture of the first metacarpal*, now known as Bennett's fracture, was presente to the Cork meeting of the British Medical Association in 1880. Five specimens were shown of un-unite fractures with secondary joint changes. The paper was published in the *Dublin Journal of Medical Scienc* 1882, 73, 72. A bronze medal now awarded to the winner of the Surgical Travelling Prize in the school o Physic Trinity College bears a portrait of Bennett on one side and the outline of a fractured first metacarpa bone on the other

As president of the British Orthopaedic Association it has been my privilege in recent months to recei e fro Dr Doolin of Dublin the very first Bennett medal ever to be cast—and it is now one of our treasured possession

[2] McNealy R. W., & Lichtenstein, M. E. "Bennett Fracture First Metacarpal." *Surg. Gyn. Obstet.*, 1932, 56, 19

[3] Dzvonogursky H. P., & Rybushkin, I. N "Fracture First Metacarpal Bone *Novi. Khir* 1933, 4, 404.

[4] Guarnieri, G "*Bennett s Fracture.*" *Riv Chir.*, 1936, 2, 292.

Fig 1005
Dislocation of the lunate

Fig 1006
Perilunar dislocation of the carpus

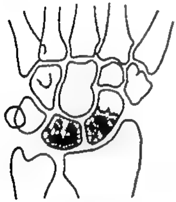

Fig 1007
Dislocation of the lunate and half scaphoid

Fig 1008
Trans-scapho-perilunar dislocation

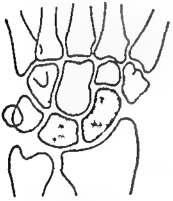

Fig 1009
Dislocation of the lunate and scaphoid.

Fig 1010
Peri-scapho-lunar dislocation

Classification of dislocations of the carpus

The dislocated bones are shown in dark shading and the undisplaced bones in pale shading Note that, in each pair the dislocation on the left is the counterpart of that on the right It is quite simple

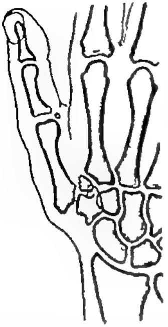

Fig 1020

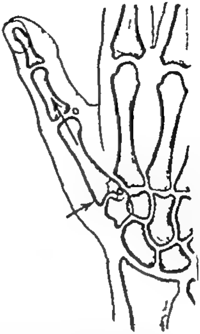

Fig 1021

Bennett's *fracture-dislocation of the thumb.* *In this injury* the thumb-metacarpal is dislocated from the trapezium. The medial basal fragment remains in normal position but the metacarpal itself slides down the saddle-shaped surface of the trapezium Even after reduction there is often need for continuous traction, or alternatively skeletal transfixion.

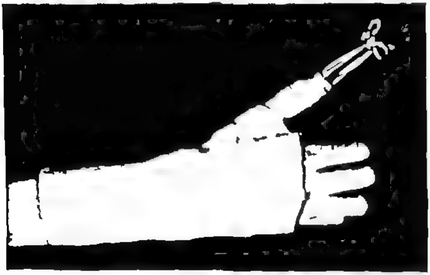

Fig 1022

The dislocation of the first metacarpal in Bennett fracture-dislocation may be held reduced by a well moulded plaster cast often with light continuous traction which in this case is maintained by tapes and collodion-gauze (some prefer pulp traction from a pin—see Figure 1048)

two or three weeks from tapes secured with collodion and ribbon gauze passed to a hook incorporated in the plaster (Fig 1022) *Only light traction* is needed for two or three weeks Some have used skeletal traction or pulp traction from a Bruck's pin (Fig 1048)[1] Others have used transfixion

[1] Haggart G L "Fractures of Metacarpals treated by Skeletal Traction." *Surg Clin N Amer* 1934 14, 1503.

or the trapezoid—or the rest of the carpus may be dislocated from these bones There is no limit to the combinations of displacement that are possible Some are illustrated in Figures 1005-1010 Of these injuries, the commonest is backward dislocation of the carpus from the lunate and proximal half of the scaphoid—*trans-scapho-perilunar dislocation of the carpus* But let us first consider dislocations of the lunate alone because it may make it easier [1-9]

Forward dislocation of the lunate—The lunate is a wedge-shaped bone *with its broad base forwards The pocket in which it lies between the radius and capitate protects it from backward displacement but a fall on the*

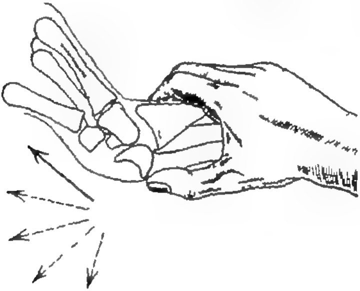

Fig 1011

Watson-Jones technique for reduction of dislocation of the lunate. *The capitate is pulled from the radius with one hand* and the lunate is pressed back with the thumb of the other Sometimes an assistant should maintain traction on the wrist *while the surgeon uses both his thumbs to tilt the lunate back.*

outstretched hand may squeeze it forwards, as a pea from a pod so that it *tilts out of the wrist joint with the head of the capitate behind the cup of* the lunate

Radiographic diagnosis—Few injuries are more commonly overlooked In antero-posterior radiographs the bone appears in sector-shaped profile like a slice of cheese whereas the outline should be quadrilateral In lateral *projection the cup of the lunate is tilted forwards with the* head of the capitate behind it (Fig 1012) There should really be no difficulty in recognising this displacement

Manipulative reduction of the dislocated lunate—Traction should be applied to the fingers so that the capitate will be pulled away from the

Brandt, G. "Mechanism of Isolated Dislocations of the Semilunar" *Dtsch. Z. Chir.*, 1925, 190, 396.
Grimault, L. "Luxation of the Carpal Semilunar Bone." *Rev Orthopéd.*, 1927 14, 161
Mouchet, A., Mathieu, P and Bary, J *Bull. Soc. Chir Paris* 1914, 40 96.
Farr C L. "Dislocations of Carpal Semilunar Bone (twelve cases reported)." *Ann. Surg.*, 1926, 84, 112.
Connell H F "Closed Reduction of Dislocations of the Semilunar" *Ann. Surg.*, 1925, 82, 289
Fonsteg. "Dislocation of Semilunar Operative Correction." *Dtsch. Z. Chir* 1922, 177 292.
Monnard "Remote Results of Dislocation Semilunar Bone." *Rev méd. Suisse rom.*, 1925, 45, 749.
Mouchet, A *Bull. Soc Chir Paris* 1926, 52, 620.
Adams, J D "Displacement of the Semilunar Carpal Bone (twelve cases reported)." *J Bone Joint Surg* 1925, 7 665.

The treatment of this fracture is in marked contrast with that of Bennett's fracture-dislocation where reduction is unstable and the penalty of imperfect reduction is usually a painful and stiff joint

Fig 1018

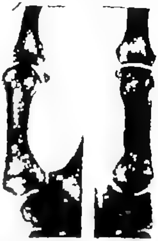

Fig 1019

A fracture of the base of the first metacarpal not involving the joint is easy to treat. All that is needed is manipulative reduction by traction with abduction and then immobilisation in a simple plaster

Bennett's fracture-dislocation of the thumb[1]—Bennett's fracture-dislocation is a more serious injury and treatment is often difficult The fracture extends through the base of the thumb metacarpal into the carpo-metacarpal joint and separates a triangular fragment from the medial side But the fractured marginal fragment is the least important part of the injury this is not really displaced—it is the metacarpal itself that is displaced and subluxated from the trapezium (Figs 1020 1021) The articular surface of the trapezium is saddle-shaped and the fracture enters the joint opposite the top of the saddle so that whereas the small fragment stays in normal position on one side nothing stops the metacarpal from sliding down the other the tension of flexor and extensor tendons pulling it down the sloping surface Thus reduction of a Bennett's fracture-dislocation of the thumb is usually unstable[2,3]

Treatment—The dislocation can be reduced by traction applied to the thumb with pressure over the base of the metacarpal While traction is maintained a plaster cast is applied and moulded closely to the base of the thumb and radial side of the carpus Some surgeons have found it possible to prevent redisplacement by moulding the plaster carefully over the base of the metacarpal bone and applying a new plaster when the first cast gets loose but I have preferred to add the safety measure of skin traction for

Edward Halloran Bennett was born in Cork in 1837 and died in Dublin at the age of seventy Having received his medical training at Trinity College he was the first graduate to be awarded the new degree of M.Ch. At the age of thirty-six he was appointed professor of surgery As curator of the Pathological Museum he arranged and catalogued a remarkable collection of fractures, dislocations, and diseases of bone The paper in which he described the fracture of the first metacarpal, now known as Bennett's fracture, was presented to the Cork meeting of the British Medical Association in 1880. Five specimens were shown of un-united fractures with secondary joint changes. The paper was published in the *Dublin Journal of Medical Science*, 1882, 73, 72 A bronze medal now awarded to the winner of the Surgical Travelling Prize in the School of Physic, Trinity College bears a portrait of Bennett on one side and the outline of a fractured first metacarpal bone on the other

As president of the British Orthopaedic Association it has been my privilege in recent months to receive from Dr Doolin of Dublin the very first Bennett medal ever to be cast—and it is now one of our treasured possessions

McNeal, H. W & Lieberstein M E "Bennett Fracture First Metacarpal." *Surg Gyn. Obstet.*, 1933, 56, 197.
Divnogorsky B F & Rybushkin, L N "Fracture First Metacarpal Bone." *Novi Khir* 1933, 4, 444.
Quaranta, C "Bennett's Fracture." *Riv. Chir* 1936, 2, 202.

radius and while such traction is maintained the lunate is pressed back into the joint Long ago I described[1] a method of reduction by applying the thumb of one hand over the front of the lunate and pulling with the other hand on the patient's wrist first in dorsiflexion and then in increasing flexion of the joint (Fig 1011) If need be an assistant should apply traction to the

Fig 1012

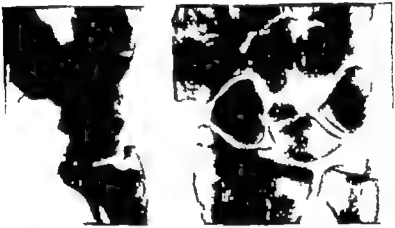

Fig 1013

Forward dislocation of the lunate

Forward dislocation of the lunate obvious in the lateral projection because the cup is tilted forwards and unoccupied by the head of the capitate behind it In antero-posterior projection the lunate is sector shaped, like a piece of cheese (Fig 1012). After reduction the head of the capitate is within the cup of the lunate and quadrilateral in shape

fingers and thumb of the patient while the surgeon presses with both thumbs over the front of the dislocated bone It is important to confirm the accuracy of reduction by immediate radiographic examination because there is no clinical test by which to be sure that the displacement is reduced A plaster cast should be applied with the wrist joint flexed about 45 degrees After one week a new plaster cast is applied with the wrist in the neutral position and immobilisation is then continued for another two weeks Full finger

[1] Watson-Jones R. "Carpal Semilunar Dislocations" Proc Roy Soc Med., 1929 22, 1071.

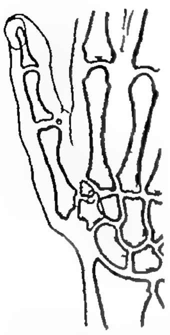

FIG 1020

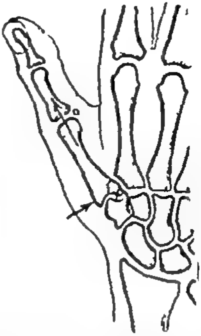

FIG 1021

Bennett's fracture-dislocation of the thumb. In this injury the thumb-metacarpal is dislocated from the trapezium. The medial basal fragment remains in normal position but the metacarpal itself slides down the saddle shaped surface of the trapezium. Even after reduction there is often need for continuous traction, or alternatively skeletal transfixion.

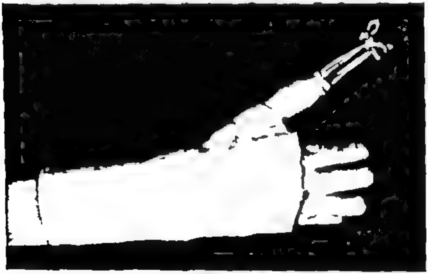

FIG 1022

The dislocation of the first metacarpal in Bennett's fracture-dislocation may be held reduced by a well moulded plaster cast often with light continuous traction which in this case is maintained by tapes and collodion gauze (some prefer pulp traction from a pin—see Figure 1048).

two or three weeks from tapes secured with collodion and ribbon gauze passed to a hook incorporated in the plaster (Fig 1022) Only light traction is needed for two or three weeks Some have used skeletal traction or pulp-traction from a Brock's pin (Fig 1048) [1] Others have used transfixion

[1] Haggart G E. "Fractures of Metacarpals treated by Skeletal Traction." Surg Clin. N Amer., 1934 14 1203.

movements should be practised throughout Complete recovery may be expected in about eight weeks

Reduction by skeletal traction—In overlooked cases where the dislocation is of many weeks standing simple manipulative reduction may fail and it is sometimes wise to use skeletal traction from a Kirschner wire driven through the necks of the metacarpal bones With such strong mechanical traction the surgeon may succeed in pushing the lunate back. In these cases the wire is an evil necessity and it should be removed as soon as reduction is accomplished there is no need at all to incorporate it in the plaster

Operative reduction—In still later cases the dislocation can be reduced only after operative exposure It should be noted, however that the results of this operation are seldom satisfactory because the dissection often

FIG 1014

Perilunar dislocation of the carpus

The lunate has remained in normal relationship with the radius, but all the other carpal bones together with the tips of the radial and ulnar styloid processes are dislocated outwards and backward

interferes with the blood supply of the bone which is imperilled already by the injury itself In such cases it has usually proved better to excise the displaced bone

Excision of the dislocated lunate—A two inch incision is made over the front of the wrist the flexor carpi radialis being retracted laterally and the median nerve and other flexor tendons medially It is not very difficult to expose the bone and remove it Thereafter some loss of strength is to be expected and there will be slight permanent limitation of movement but the results of excision of this central bone of the carpus are better than might be expected The power of the wrist and the range of movement are usually about three-quarters of normal So far the results have certainly been better than those of late operative reduction But before leaving the subject it must be emphasised once again that excision of the lunate is indicated only when this bone is dislocated—there is certainly no wisdom in excising the undisplaced lunate when the rest of the carpus is dislocated from it

FIG 1023
Bennett's fracture-dislocation of the thumb.

FIG 1024

FIG 1025

Instead of preventing redisplacement by skin traction or skeletal traction it may be prevented by transfixion. After reduction, a Kirschner wire is driven through the shaft of the thumb metacarpal into the shafts of the index and middle metacarpals, and incorporated in the plaster (This case was treated by Dr H R. C Norman and Dr Laird, of Toronto, to whom acknowledgment is made)

with a Kirschner wire or slender Steinman pin driven through the shaft of the thumb metacarpal into the shafts of the index and second metacarpal bones, incorporated in the plaster (Figs 1023 1025)

FIG. 1029

FIG. 1030

In this unusual carpo-metacarpal dislocation the bases of all four metacarpals were displaced forwards into the palm. The displacement was reduced by manipulation by Miss Pearson at Raigmore Hospital, Scotland. Note that a fragment from the base of the index metacarpal remained displaced in the palm. Functional recovery was complete.

by massage or passive stretching must be avoided Such treatment delays recovery

Dislocation of the fingers—Dislocation usually occurs from hyperextension injury and the phalanx is displaced backwards Reduction is easily accomplished by traction and flexion of the joint The finger should be immobilised in a flexed position for two or three weeks by a small plaster cast or collodion gauze dressing

Fracture-dislocation of the fingers—Interphalangeal dislocations may be accompanied by chip fractures from the joint margin Slight separation of small fragments does not influence the treatment or prognosis—recovery will always be slow but when a fragment is more widely displaced tilted out of position or rotated, early operative replacement through a short incision is advisable These fracture-dislocations are unstable and there is a marked tendency to recurrence of dislocation Even a complete plaster cast may not prevent redisplacement The injury is comparable to Bennett s fracture-dislocation of the thumb and continuous traction is sometimes needed by collodion gauze extension tapes or even a pulp-traction pin (Fig 1048) Immobilisation is needed for at least three weeks

MALLET FINGER AND OTHER INJURIES

Avulsion of the extensor tendon of a finger from its insertion into the base of the terminal phalanx is the most frequent of all subcutaneous tendon ruptures It usually occurs from forcible flexion of the finger while the tendon is actively contracting or less commonly from a sharp blow directly over the tendon insertion It may therefore be sustained by cricket and baseball players by housewives who stub the tip of a finger while making beds and smoothing out sheets or by pianists who strike a note with such vigour that the end of the finger doubles under Three types of mallet finger may be distinguished 1) avulsion of the tendon without bone injury 2) avulsion of the tendon with detachment of a triangular fragment from the base of the phalanx 3) avulsion of the tendon in children with displacement of the whole epiphysis at the base of the phalanx

Disability in untreated cases—The power of the tendon over the terminal joint of the finger is lost and although passive extension is normal the joint cannot be extended actively The unopposed pull of the long flexor tendon gives rise to about 60 degrees of flexion deformity and a typical mallet finger A secondary disability often develops at the proximal interphalangeal joint which may prove even more incapacitating than the deformity at the terminal joint The extensor tendon divides over the back of the proximal phalanx into a central slip which extends the proximal interphalangeal joint and two lateral slips which fuse together and pass to the terminal joint Since the lateral slips are torn from the terminal phalanx they retract as far as the central slip will allow and add their quota of power to it In this way the proximal joint becomes hyperextended A fully developed mallet finger consists therefore of flexion deformity at the terminal joint which cannot be fully extended and hyperextension deformity at the proximal interphalangeal joint which cannot be fully flexed

Conservative treatment—This relationship of the lateral and middle slips of the extensor tendon has an important bearing on treatment Complete

FIG 1023
Bennett's fracture-dislocation of the thumb.

FIG 1024

FIG 1025

Instead of preventing redisplacement by skin traction or skeletal traction it may be prevented by transfixion. After reduction, a Kirschner wire is driven through the shaft of the thumb metacarpal into the shafts of the index and middle metacarpals, and incorporated in the plaster (This case was treated by Dr H R C Norman and Dr Laird, of Toronto, to whom acknowledgment is made)

with a Kirschner wire or slender Steinman pin driven through the shaft of the thumb-metacarpal into the shafts of the index and second metacarpal bones, incorporated in the plaster (Figs 1023 1025)

recovery is possible only if the raw area of bone on the terminal phalanx is opposed accurately to the retracted extensor tendon It is obvious that the terminal joint must be held in full hyperextension, but it is less well recognised that the proximal joint must be held in flexion in order to overcome the retraction of the extensor tendon Flexion of this joint puts tension on the middle slip of the tendon and pulls it distally Since the lateral slips are attached to the middle slip they also are pulled distally nearer to the bone from which they have been avulsed This can be proved in any normal finger Hold the proximal inter phalangeal joint of one finger flexed to the right angle All power of the extensor tendon over the terminal joint has then disappeared this joint is flaccid and powerless because the lateral slips have been pulled distally and cannot retract and tighten.

FIG. 1050
Mallet finger with chip fracture base of phalanx.

The position that is needed can be maintained only by a plaster cast No splint has been devised that will hold the terminal joint in full hyperextension and the proximal joint in moderate flexion—and preserve us from the proposals recently made of intramedullary fixation by pins driven through the pulp across the phalanges and interphalangeal joints

The application of a plaster which will effectively immobilise a mallet finger in the required position is not easy (Figs 1053-1054) The cast must extend from the web to the tip of the finger as far as the nail margin and it should extend laterally to cover three-quarters of the surface The dry plaster six or eight layers thick, having been cut to this size is soaked and bound to the finger with ribbon gauze The surgeon immediately grips the terminal joint between his thumb and index finger and hyper extends it to the limit of this movement With his other hand he holds the proximal joint flexed almost to the right angle The position is held firmly until the plaster is set Smillie described a simple method in which the patient himself maintained the correct position by gripping between finger tip and thumb while the plaster set [1]

FIG 1051

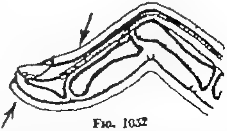

FIG. 1052

The fully developed mallet finger is a flexion deformity at the terminal joint and a hyperextension deformity at the proximal joint (Fig. 1051). The terminal joint must be hyperextended to the limit and the proximal joint must be flexed.

Operative treatment—The view has sometimes been expressed that it is impossible to secure perfect results from non-operative treatment of a mallet finger There can be no doubt that this view is mistaken If the details of technique are carefully carried out and immobilisation is continued for not less than six weeks it is usually impossible to judge which finger has been injured (Fig 1055) When a fragment of bone is avulsed, perfect results are nearly always possible When there is no fracture the proximal part of the tendon may be partly turned into the joint and there is greater justification for operative treatment

[1] Smillie, I. S "Mallet Finger" *Brit J Surg* 1937 24 439.

FIG. 1029

FIG. 1030

In this unusual carpo-metacarpal dislocation the bases of all four metacarpals were displaced forwards into the palm. The displacement was reduced by manipulation by Miss Pearson at Raigmore Hospital, Scotland. Note that a fragment from the base of the index metacarpal remained displaced in the palm. Functional recovery was complete.

It must be understood however that suture of the avulsed tendon with catgut may be very difficult The tendon lies so superficially under a thin layer of skin that breakdown of the wound with sinus formation and discharge of the catgut is by no means uncommon Operative suture of

FIG 1053

FIG 1054

Plaster for mallet finger The dry cast is cut to the correct size and shape (Fig 1053). It is soaked, bound on with ribbon gauze and the finger is held fully hyperextended at the terminal joint and flexed at least 60 degrees at the proximal joint.

extensor tendons avulsed from the terminal phalanx should be undertaken only by those who are well trained in the surgery of the hand They may perhaps use fine wire sutures of the pull-out type described by Bunnell [1] in which the stitch passes from the proximal end of the tendon through the terminal phalanx to emerge through the pulp of the digit

There is a stronger indication for operative treatment in old mallet finger

[1] Bunnell, S "Surgery of the Hand," 2nd ed. J B. Lippincott Co., 1944.

FRACTURES OF THE SHAFTS OF THE METACARPALS

The only frequent disability after fractures of the shafts of the metacarpal bones is stiffness of the fingers from excessive immobilisation The practice of binding the fingers over a roll of bandage in the palm or strapping the *fingers and hand to a flat splint may be disastrous The lateral* support and fixation of the metacarpal bones by the muscles and fascial tissues between them minimises displacement and controls mobility of the fractured fragments so that mal union and non union are no more frequent than in fractures of the ribs which are similarly anchored Angulation of the fragments should be corrected by manipulation but the only immobilisation usually needed is that of a simple dorsal plaster cast which leaves the fingers free for exercise at all joints including the metacarpo-phalangeal joints. Occasionally displacement cannot be reduced by manipulation and it may then be wise to replace and impact the fragments through a short incision. But even in these cases there should seldom be need for internal fixation by plates screws, intramedullary pins and pegs which recently have been used rather wildly and indiscriminately in this very simple fracture from which functional recovery is nearly always perfect after conservative treatment *even when there is slight over riding of the fragments*

Spiral fractures—A fall on the ulnar border of the hand with rolling movement on to the dorsum often causes spiral fracture of the shafts of the fourth and fifth metacarpal bones and sometimes of the third [1] There may be slight shortening from over riding but this does not interfere with function Treatment by continuous traction with its usual penalty of stiffness of joints is unnecessary Excellent results can be achieved by the simple application of a dorsal plaster cast to which the hand is firmly strapped

Transverse fractures—Transverse fractures may give rise to more difficulty They occur in the shafts of the first and fifth metacarpals which are exposed to direct injury Loss of apposition of the fragments with over riding and backward angulation should be corrected Accurate reduction and suitable immobilisation are important because otherwise there may be danger of non union especially in the index metacarpal If manipulative reduction fails the fragments should be exposed through a short incision and be impacted into each other The problem of un united gap-fractures of the index metacarpal and of the treatment by bone-grafting was discussed in the first volume (p 328 Figs 545-547)

FRACTURE OF THE NECK OF THE METACARPAL

Fracture of the neck of the fifth metacarpal is the second commonest bone injury in the hand A similar fracture may occur in the neck of the index metacarpal where failure of reduction leads to even more serious disability The head of the metacarpal is tilted forwards towards the palm the fracture being angulated backwards It is a mistake to attempt reduction or

[1] Iogroscino, D "Spiral Fractures of the Metacarpals." *Chir Organi Mov.*, 1937 22, 479.

injuries of many weeks or months duration An ellipse of stretched and elongated scar tissue is excised from the back of the terminal interphalangeal joint and the proximal stump of the tendon is sutured to the terminal phalanx by a pull-out stitch

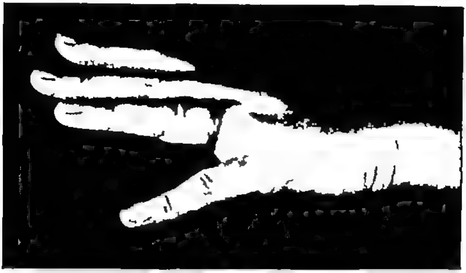

Fig 1055

Mallet finger from avulsion of the tendon without chip fracture after conservative treatment by simple immobilisation in plaster with the terminal joint hyper extended and the proximal joints flexed. It is almost impossible to judge which finger has been injured; in fact it was the ring finger

Fig 1056

Avulsion of the middle slip of the extensor tendon from the base of the middle phalanx. Four months old injury Note the slight hyperextension deformity at the terminal joint.

Avulsion of the middle slip of the extensor tendon—The opposite deformity to that of mallet finger may arise from avulsion of the middle slip of the extensor tendon from the base of the middle phalanx The proximal interphalangeal joint is flexed Without suitable treatment all the power of the extensor tendon is concentrated on the terminal joint which gradually hyperextends (Fig 1056) Furthermore avulsion of the middle slip of the

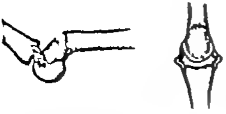

FIG 1031

FIG 1032 FIG 1033 FIG 1034

Hyperextension does not reduce a *forwardly displaced fracture of the neck of the* metacarpal because the capsule is relaxed (Fig 1031) The shape of the metacarpal head is such that the lateral ligaments and capsule are taut only in flexion (Fig 1032) Thus fractures of the neck of the fifth metacarpal with forward displacement of the head should be reduced by flexing the metacarpo-phalangeal joint to the right angle and then thrusting back the phalanx and head of the metacarpal (Figs 1033-1034).

FIG 1035

Plaster cast for fracture of the neck of the fifth metacarpal. The finger is flexed to the right angle at the metacarpo-phalangeal and interphalangeal joints, and while the plaster is setting the backward thrust on the proximal phalanx is maintained. The pressure points need protection with thin felt.

immobilisation of this fracture by hyperextension of the metacarpo-phalangeal joint The shape of the metacarpal head is such that the lateral ligaments are taut in the flexed position and relaxed in the extended position (Figs 1031 1032) This is why the fingers can be abducted and rotated when they are in extension but not when the metacarpo-phalangeal joints are flexed to the right angle Hyperextension of the joint relaxes the capsule so completely that it does not pull the displaced metacarpal head back into position On the contrary pressure of the base of the phalanx

extensor tendon may produce one type of trigger or snap finger When the finger has first been straightened passively the patient may be able to hold it straight actively the proximal interphalangeal joint being extended by the two lateral slips of the extensor tendon but as soon as the patient flexes the finger the lateral slips jerk sideways over the head of the phalanx It is then impossible to extend the finger until passive assistance has been given As the finger is passively straightened the lateral tendons snap back from the side to the dorsal aspect of the proximal joint and a trigger effect is produced

In recent injuries simple immobilisation in a plaster cast with the proximal joint extended is nearly always successful In older injuries, operative repair of the tendon may be needed

FIG. 1057

Ring avulsion of the skin of the finger

The patient was jumping off the tail-board of a truck and caught his ring in a nail. The ring was torn off, carrying with it the skin and subcutaneous tissues.

Ring avulsion of the finger—During the last war many soldiers hitch hiked to and from leave but for men wearing rings there was special peril in travelling on the back of a lorry In dismounting hurriedly the ring often caught on a hook or nail so that the finger was stripped of skin (Fig 1057) The flexor and extensor tendons were exposed It is perhaps tempting in these cases to replace the skin by grafting placing the denuded digit under the skin of the abdominal wall with later completion of plastic repair but there are two reasons why such treatment usually fails 1) the flap tends to ulcerate because the supply of blood received from the denuded base is insufficient both digital arteries having been avulsed 2) the interphalangeal joints remain stiff by reason of ischæmic contracture and fibrosis of the capsule and tendons Very often after many months of treatment the residual disability was so great that amputation was inevitable It is usually better to adopt amputation as the primary treatment especially since the value of this particular finger is more sentimental than functional

on the back of the metacarpal head pushes it still further forwards the relaxed capsule then contracting with adhesion of its folds. Permanent stiffness of the joint is the inevitable sequel.

Treatment—The best method of reduction is to flex the metacarpo-phalangeal joint to the right angle and press backwards in the axis of the phalanx so that the metacarpal head is pushed back.[1] Whatever the degree of displacement there is little difficulty in correcting it (Figs 1033-1034). A dorsal plaster cast should be applied from the upper forearm to the level of fracture The finger is then flexed to the right angle at the metacarpo-phalangeal and interphalangeal joints, the skin over the interphalangeal joint being protected with felt A narrow plaster strip is placed over the extensor surface of the flexed finger and incorporated in the main cast While the plaster is setting backward pressure is maintained (Fig 1035). Immobilisation is needed only for three weeks

SPRAINS AND DISLOCATIONS OF THE METACARPO-PHALANGEAL JOINTS

Sprain of the metacarpo-phalangeal joint of the thumb causes swelling with tenderness when the joint is pressed laterally or obliquely All that is usually needed is to protect the joint by firm strapping for a week or two.[2] Sometimes however the lateral ligament is completely ruptured and this may cause serious and permanent instability unless the joint is immobilised promptly and for several weeks. If it is not so protected the ligament heals with lengthening which causes habitual subluxation of the joint—in fact it displaces every time that an attempt is made to grip securely between the tips of the thumb and index finger It is seldom difficult to establish the clinical diagnosis because there is obvious lateral instability But if there is doubt radiographs should be taken with the thumb in lateral and medial deviation, perhaps being compared with similar radiographs of the normal thumb There may be a chip fracture from the base of the phalanx or from the metacarpal head (Fig 1036) This small fragment may not only be tilted from its bed but also rotated so that the fractured surface lies superficially (Fig 1037) It is important to correct such displacements through an open incision and to replace the fragment in its bed, sometimes with one catgut suture in the capsule and periosteum in order to prevent persistent weakness and pain Occasionally the fragment avulsed from the phalanx may be displaced into the joint just as the epicondyle of the humerus is sometimes displaced into the elbow joint Any fragment torn from the base of the phalanx which is rotated, retracted or displaced into the joint should be replaced by open operation and the thumb should be immobilised in plaster for at least three weeks Exactly the same principles of treatment apply to sprains chip-fractures and momentary subluxations of the metacarpo-phalangeal and interphalangeal joints of the fingers as illustrated in Figures 1038-1039

[1] Jahss, S A. Fractures of Metacarpals. *J Bone Joint Surg.*, 1938 20, 1 4.

[2] *Crush fracture of the sesamoid bone of the thumb—Injury of the thumb from direct violence presenting the clinical features of sprain, is sometimes found to be associated with crush fracture of the sesamoid bones.* There is local pain, tenderness, swelling and limitation of movement, the thumb being held in the semiflexed position. If the joint is protected, recovery is usually complete within a week or two. (W H. Noble. "Crush Fracture of Sesamoid Bone of Thumb." *Brit. med. J.*, 1941 2, 912.)

Fig 1036

Fig 103

Chip-fracture from the base of the phalanx usually indicates a momentary subluxation rather than a simple strain of the joint and this is why the disability is prolonged (Fig 1036). If the fragment is tilted or upside down (Fig 1037), or included within the joint, operative replacement is advisable—or even essential.

Fig 1038

Fig 1039

The chip-fractures in Figures 1036 1037 were from the side of the base of the phalanx from lateral strain of the thumb These two examples are from the front of the base of the phalanx from hyperextension strain of the finger The significance is the same they were momentary subluxations.

Dislocation of the metacarpo-phalangeal joint of the thumb—Dislocation of the metacarpo-phalangeal joint of the thumb is usually associated with backward displacement of the phalanx (Figs 1040 1041) and occasionally with forward or lateral displacement Reduction may be accomplished by applying traction with direct pressure over the displaced bone Sometimes the head of the metacarpal is driven forwards through a vertical split in the capsule which closes on the neck like a buttonhole round a button and moreover the sesamoids of the flexor pollicis longus may be interposed between the articular surfaces In these cases operative reduction is needed.

Fig 1040

Fig 1041

Dislocation of the metacarpo-phalangeal joint of the thumb in a child before and after manipulative reduction.

Fig 1042

Fig 1043

Dislocation of index metacarpo-phalangeal joint with buttonholing of the capsule needing operative reduction.

PART IV

INJURIES OF THE LOWER LIMB

A lateral incision may suffice but if not a three-limbed incision should be used—vertically on the medial side of the phalanx crossing transversely in front of the joint in the line of the flexor crease and then vertically on the *lateral side of the metacarpal neck* *At all costs there must be no midline incision over the palmar surface of the thumb* The interposed tissues, whether capsule periosteum or sesamoid bones, are easily hooked out and the dislocation is reduced The skin wound is closed usually without any deep sutures (Figs 1042 1043)

FRACTURE OF THE PROXIMAL PHALANX

One of the commonest injuries of the fingers is fracture of the proximal phalanx with forward angulation.[1,2] The displacement is maintained by the pull of the lumbrical and interosseous muscles which pass from the front of the metacarpal to the back of the distal part of the phalanx (Fig 1044) This is a very characteristic injury with typical displacement and unfortunately with typical disability unless it is correctly treated The principles of treatment were discussed in the first pages of this chapter If accurate reduction is not achieved by traction and flexion with immobilisation thereafter in the flexed position a serious disability arises because the forwardly angulated fragments encroach upon the flexor tunnel and restrict movement of the flexor tendon sometimes even causing complete and permanent stiffness of all the joints

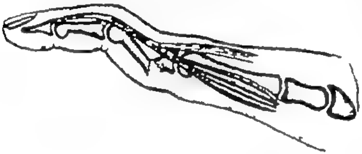

Fig 1044

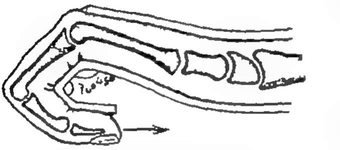

Fig 1045

A fracture of the proximal phalanx angulates forwards owing to the pull of the interosseous and lumbrical muscles (Fig 1044) It must be reduced and immobilised in flexion (Fig 1045)

It is seldom difficult to reduce the displacement by applying traction and flexing the finger A light plaster cast should then be applied, holding the metacarpo-phalangeal joint in 45 degrees of flexion and the proximal interphalangeal joint in about 90 degrees of flexion it may be applied either on the palmar or the dorsal surfaces Very often the obliquity of the fracture line is such that the fragments are quite stable in this position (Figs 1046-1047) After immobilisation for two or three weeks, active exercises may be practised Occasionally the fracture is more unstable and pulp traction may perhaps be advisable during the first week or ten days If so a Brook s pin is driven through the pulp fixed by very light

[1] Ryder D L. "Fractures of Metacarpals and Phalanges." *Amer J Surg.*, 1937 n.s. 38, 549.
[2] Owen, H R. "Fractures of the Bones of the H nd." *Surg Gynec. Obstet.*, 1938, 66, 500.

Fig 1046

Fig 1047

Fracture of the proximal phalanx with typical forward angulation maintained by the pull of lumbrical and interosseous muscles. The obliquity of the fracture line is such that it is often quite stable in a simple plaster cast in the flexed position. Continuous pulp traction or skeletal traction is seldom needed.

Figs. 1048 1049

Pulp traction for unstable fractures and fracture-dislocations of the phalanges. Note the axis of flexion. In the flexed position, only the middle finger lies parallel with the axis of the corresponding metacarpal bone. The other fingers flex in an oblique axis, each pointing to the tubercle of the scaphoid.

screw traction to a hook incorporated in a forearm plaster (Fig 1048) But it is seldom needed

The fingers do not flex in a parallel axis in line with the forearm—A very frequent error of treatment arises from the belief that when the fingers are fully flexed they lie in the same parallel axis that they occupy in the extended position This is not so If the fingers are flexed in turn it will be found that they converge and that their tips all touch the same part of

CHAPTER XXIV

INJURIES OF THE HIP

The ball-and-socket shape of the hip joint, together with the thickness of the capsule and the arrangement of bone lamellæ in the lines of stress of the femoral neck, account for its strength and stability. Nevertheless the joint is unusually susceptible to injury at three stages of life. In adolescence before the epiphysial lines have fused there may be avulsion of the trochanteric epiphyses or displacement of the upper femoral epiphysis. In old age when there is senile osteoporosis the femoral neck may be fractured by simple stumbles or trivial strains. Even in middle life, when the defences seem most sound, there is one position in which the joint is vulnerable to injury—if the femur is flexed to the right angle and adducted it is held in position only by capsule, and a forcible thrust along the line of the femur may dislocate the joint. Thus three groups of injury in the region of the hip joint must be considered: 1) avulsions and displacements of epiphyses near the hip; 2) traumatic dislocations of the hip; 3) fractures of the neck of the femur.

AVULSION OF EPIPHYSES NEAR THE HIP JOINT

Avulsion of the lesser trochanter—The epiphysis of the lesser trochanter is sometimes avulsed by the powerful iliopsoas muscle (Fig. 1058). Like other tendon ruptures and avulsions the injury occurs from active contraction of the muscle against the resistance of a strain in the opposite direction. The usual cause is a tackle at rugby football or an attempt to stop suddenly when running at speed. The psoas tendon is attached to the epiphysis itself, but the iliacus is inserted into a broader area of the femoral shaft and thus often limits the degree of displacement. Moreover, the epiphysis fuses to the femur at the age of eighteen years, and avulsion of the iliopsoas after that age is exceptional, although one case has been recorded of an avulsion fracture of the lesser trochanter sustained by an adult during a wrestling match. Operative treatment is not indicated. If the hip is flexed through 90 degrees the raw bone surface of the femur is brought up to the retracted fragment and the position can be maintained by a simple arrangement of pillows. There is no need for complete immobilisation in splints or plaster, but the patient should stay in bed for three or four weeks.

Avulsion of the greater trochanter—A direct blow over the greater trochanter may cause an isolated fracture[1] but complete separation and displacement of the trochanter usually occurs from muscular violence, the abductor and lateral rotator muscles avulsing the bone fragment which is retracted so that it lies above the neck of the femur. Operative reduction

[1] Betto, G. "Isolated Fracture Great Trochanter." *Chi. Org. i Mov.*, 1936, 22, 58.

the palm near the base of the thenar eminence The axis of movement is not parallel with the long axis of the limb except in the case of the middle finger Each finger in the flexed position points to the tubercle of the scaphoid Only by passively straining and twisting the joints can the flexed fifth finger be made to lie parallel with the corresponding metacarpal so that it touches the hypothenar eminence

This radiation of the axes of flexion of the fingers presents an interesting study in the anatomy and the function of the hand The shape of the metacarpal heads is such that the lateral ligaments of the metacarpo-phalangeal joints are relaxed in extension and taut in flexion (see Figs 1031 1032) In the extended position the fingers must be free to act independently and it must be possible to separate them freely from each other Accordingly in the extended position the metacarpo-phalangeal capsules are relaxed and adduction-abduction movements are possible. In the flexed position there is no such demand for independent action. When the fingers grip an object tightly in the palm they act only in unison, and their united strength is augmented when each is pulled tightly to the side of its neighbour The smaller the object that is held and the tighter the grip that is called for the more closely must the fingers approach each other Their axes of flexion must therefore converge and this is achieved by increased tightening of the capsular ligaments The more the metacarpo-phalangeal joints are flexed the more the capsules tighten, and the more closely the fingers lie

The practical inference is that each finger must be immobilised in such an axis of flexion that it points to the region of the scaphoid tubercle (Fig 1048) If the fifth finger is immobilised in the position illustrated in many textbooks pointing to the region of the pisiform the fracture will unite with rotational displacement and deformity with restricted function will remain permanently

The usual care must be taken to avoid interference with the movement of other fingers Full active exercises are to be practised throughout the period of immobilisation After three weeks the plaster may be removed, and movements are then restored to the injured finger by the patient's own exercise and not by passive stretching or manipulation

INTERPHALANGEAL SPRAINS, SUBLUXATIONS AND DISLOCATIONS

Sprain of the finger joints—The interphalangeal joints are no less susceptible to injury than the metacarpo phalangeal joints and the period of disability is no less prolonged Radiographs may show small chips of bone detached from the joint margin by avulsion of the capsule in other cases the capsule itself is torn Many finger sprains have been momentary dislocations spontaneously reduced immediately after injury The joint should be protected for a week or two by collodion-gauze dressing applied while the finger is held in slight flexion Collodion is painted on the skin and ribbon gauze is bandaged over it Four or five alternate layers of collodion and gauze complete the dressing which dries to form a sufficiently rigid yet less bulky splint than plaster Recovery is sometimes slow and it may be several months before swelling of the joint subsides and full movement is restored *Throughout this time the temptation to accelerate progress*

with nailing of the fragment is seldom needed (Fig 1059) When the hi abducted the upper shaft of the femur is brought into accurate appoxt with the avulsed trochanter and firm union is secured if the position maintained by means of a plaster spica for about six weeks

Avulsion of the epiphyses of the iliac spines—Avulsion of the epiphy of the anterior inferior iliac spine by the rectus femoris and of the ante superior iliac spine by the sartorius, will be discussed in a later chapter

FIG 1038

Avulsion of the epiphysis of the lesser trochanter by the iliopsoas muscle.

FIG 1039

Avulsion of the greater trochanter by the abductor muscles of the hip.

DISPLACEMENT OF THE UPPER FEMORAL EPIPHYSIS

Adolescent Epiphysial Coxa Vara—Epiphysiolysis Capitis Femoris

Several features distinguish slipping of the upper femoral epiphysis fro the displacements caused by injury to other epiphyses at the ends of lo bones This epiphysial displacement occurs almost solely in boys adolescent years many showing evidence of hypopituitarism or hypogonadis with obesity and sexual immaturity and some few giving a history of rece rapid growth so that the boy is tall and slender [1] Moreover although tl line of separation is at the usual level of the junction of the metaphysis wi the epiphysial cartilage the epiphysis in its backward and downwar displacement does not carry with it a triangular fragment from the margi of the diaphysis over which it is displaced as it does in other epiphysi injuries [2] The frequency of simultaneous involvement of both hip joint often without history of injury to either indicates that the lesion is not simple traumatic displacement *About 70 per cent of the displacement arise without recognised injury* and even in other cases there is seldom sever injury causing *immediate and complete displacement* More often a strai

[1] Key J A. Epiphyseal Coxa Vara. *J Bone Joint S rg* 1926, 8, 53.
[2] Perkins, G *Brit. med. J* 1932, 1 55.

is followed after some weeks or months by increasing disability with evidence of progressive epiphysial slipping Indeed the whole displacement may arise while the patient lies in bed It is sometimes found that while one hip has been treated for epiphysial displacement by immobilisation and traction the epiphysis of the opposite hip, which has not been immobilised has been slipping gradually and unobserved One case is recorded of severe displacement developing while the affected hip was immobilised on an abduction frame [1] Evidently there are predisposing factors causing such a degree of epiphysial separation that simple muscle retraction produces the displacement The predisposition is observed only between the ages of twelve and seventeen years [2] the longest interval in bilateral cases between the onset of slipping on one side and on the other being about eighteen months The underlying factor is not always evident, but sometimes it is quite obvious The boy is excessively fat and there is delayed sexual maturity with undeveloped testicles and absence of pubic and axillary hair—hypopituitarism of the Fröhlich type or hypogonadism described as adipose gynandrism (p 390) Occasionally the displacement arises from failure of epiphysial calcification in renal rickets (p 388) [3-5]

Etiology—The etiological factors may therefore be summarised under three headings 1) an endocrine disorder with deficiency of sex hormone or perhaps excess of growth hormone predisposing to slipping of the epiphysis during a period of two or three years in adolescence [6], 2) muscle retraction producing gradual and insidious displacement without injury and even without weight-bearing 3) occasionally an injury such as a severe wrench or stumble which precipitates the displacement acutely

Pathological anatomy—The primary and important displacement of the epiphysis is not downwards but backwards and epiphysial coxa vara is a less accurate anatomical description than epiphysial coxa anteverta.[7] As the epiphysis rotates backwards it reaches the limit of stretching of the ligamentum teres but this does not arrest the displacement The limb rotates laterally in order to maintain a more or less central position of the epiphysis in the acetabulum and the more the epiphysis displaces the greater is the development of lateral rotation deformity Ultimately the epiphysis can slip no more because its lower margin locks in the digital fossa and the lateral rotation deformity then amounts to 90 degrees

Clinical diagnosis—The clinical signs of a severely displaced upper femoral epiphysis are easily recognised An adolescent boy either obese with sexual immaturity or unusually tall and slender has limitation of all hip movements with slight shortening of the limb but there is no flexion adduction deformity whereas there is from 40 to 90 degrees of lateral rotation deformity These signs are unmistakable But they should never

Mayer L. *J Bone Joint Surg.*, 1937 19, 1046.
Of course, in Simmonds' disease where hypopituitarism from injury persists into adult life, and a man of twenty-six years looks like a boy of twelve the displacement may occur at any age. (Farrow F *J Bone Joint Surg* 1953 35-B, 422.)
Bradford, J F "Radiology of Bones and Joints," page 186. London J & A. Churchill Ltd., 1934.
Price V L., and Davie, T. B. "Renal Rickets." *Brit. J Surg* 1937 24, 548.
Wardle, E. N "Slipped Epiphysis of the Head of the Femur. *Brit. J Surg.*, 1933, 21, 312.
Sex-hormone and growth-hormone in relation to epiphysial displacement—In an experimental study—"The endocrine basis for slipping of the upper femoral epiphysis," *J Bone Joint Surg.*, 1950, 32-B, 5.—W Robert Harris showed that sex-hormone increases the shearing strength of the epiphysial plate and growth-hormone reduces it He suggested that these findings might be significant in displacements of the upper femoral epiphysis which occur so often in association with the adiposo-genital syndrome or with rapid adolescent growth, in which there is relative lack of sex-hormone and relative excess of growth-hormone.
Key H. "Epiphysiolysis or Epiphysial Coxa Anteverta." *J Bone Joint Surg* 1937 19, 97

Although most dislocations of the hip joint are sustained from a backward drive on the femur in its adducted position there may also be dislocation when the flexed joint is not fully adducted as for example, from a fall of roof on the back of a stooping miner In this position the femoral head is at least partly protected by the acetabulum and when it is driven backwards the posterior lip of the acetabulum is usually fractured and displaced with it [1] If the thigh is not adducted at all, or is even very slightly abducted at the moment of impact a central fracture-dislocation may be produced with comminution of the floor of the acetabulum Furthermore a fall of roof on the back of a miner whose hip joints are widely abducted may cause

FIG 1073

FIG 1074

Posterior view of the hip joint with the femur in the neutral position (Fig 1073) and in the flexed-adducted position (Fig. 1074). It is obvious that the stability of the "ball and socket joint" applies only when the limb is in the neutral position. When the limb is flexed and adducted the head of the femur is kept in position only by capsule. In this position the joint is vulnerable to posterior dislocation—to paralytic dislocation if there is over-action of the flexor-adductor muscles, to pathological dislocation if the flexor adductor muscles are in spasm, and to traumatic dislocation from longitudinal thrusts on the flexed and adducted femur

anterior dislocation [2-3] The head of the femur then lies over the obturator foramen or on the pubic crest Falls of roof may produce bilateral anterior dislocations of the hip joints and more than fifty such cases have been recorded [4-6] Indeed one dislocation of the hip has been reported where the femoral head was driven into the scrotum.[6] Sometimes there has been buttonholing needing open reduction [7-8]

Campbell, W. C. "Posterior Dislocation of the Hip-Joint with Fracture of the Acetabulum" (report of eighty cases). *J. Bone Joint Surg.*, 1936, 18, 842.
Buxton, St. J. D. "Traumatic Anterior Dislocation of the Hip." *Proc. Roy. Soc. Med.*, 1933, 27, 570.
Macfarlane, J. A. "Anterior Dislocation of the Hip." *Brit. J. Surg.* 1936, 23, 607
Wolff, H. B. "Bilateral Traumatic Dislocation of the Hip-Joints." *Brit. med. J.*, 1930, 77, 626.
Marquard, W. "Bilateral Traumatic Dislocation of Hips—Review of Fifty-two Reported Cases." *Arch. Orthop. Mech. Ther.*, 1936, 37, 169
Goetz, A. G., and Marquard, W. "Traumatic Dislocation of the Hip into the Scrotum." *J. Bone Joint Surg.*, 1934, 16, 718.
Macfarlane, J. A. "Anterior Dislocation of the Hip." *Brit. J. Surg.*, 1936, 23, 607
Henderson, R. S. "Traumatic Anterior Dislocation of the Hip." *J. Bone Joint Surg.*, 1951, 33-B, 602.

have arisen the diagnosis has been made too late If the epiphysis is already displaced and fixed in its deformed position a perfect result is difficult to achieve no matter what the treatment may be whereas if efficient treatment is begun in earlier stages the results are uniformly good.[1] A *provisional* clinical diagnosis can always be made before there is fixed lateral rotation deformity and only then is there any certainty of avoiding residual disability

Early clinical diagnosis—If a boy aged from twelve to seventeen years develops intermittent limp and complains of occasional stiffness in the thigh, slipping of the upper femoral epiphysis should be suspected Pain in the thigh and knee is even more frequent than pain in the hip The symptoms are *typically intermittent* and in the intervals the patient may run, jump and pursue normal recreations The important clinical sign is the *limitation of medial rotation movement of the hip joint* The range must be estimated accurately in degrees the common practice of perfunctorily rolling the extended limb is useless The *hip and knee joints should be flexed to the right angle* the leg from knee to ankle being used as the arm of a protractor and it is then easy to demonstrate that medial rotation movement is less than the normal 30 to 40 degrees. The range of lateral rotation may be somewhat greater than the normal 50 or 60 degrees. Moreover it is impossible to flex the hip joint fully in a normal manner so that the knee touches the front of the chest Backward

Fig 1060

Is this a normal hip? Can displacement of the upper femoral epiphysis be excluded by this radiograph? See Figures 1061 1062.

and downward rotation of the femoral head has imposed a new axis of flexion movement on the joint and the more it is flexed the more the knee moves away from the midline In full flexion of the hip joint the knee lies at the side of the chest near the axilla and the limb is laterally rotated *All these clinical signs may not be present* It is enough that an adolescent boy has complained of intermittent limping or stiffness and that medial rotation movement of the hip is restricted On these grounds alone complete radiographic examination is imperative

Radiographic diagnosis of displacement of the upper femoral epiphysis—*Look at the radiograph in Figure 1060 Is this a normal hip joint?* There is no obvious abnormality and some surgeons might say that the joint is normal—but a lateral radiograph taken on the same day shows an advanced degree of slipping of the epiphysis which has reached almost the

[1] Pomeranz, M. M. and Sloane M. F Slipping of Proximal Femoral Epiphysis—Results in One Hundred and One Cases. *Arch Surg* 1935 30, 607

Summary of the mechanism of dislocation of the hip—It is thus evident that the more completely the hip joint is adducted at the moment of injury the more certainly will the joint be dislocated backwards without fracture. With lesser degrees of adduction the backward dislocation will often be accompanied by fracture of the margin of the acetabulum If the thigh is not adducted or is slightly abducted at the moment of impact there may be a central fracture-dislocation of the hip joint If the hip joint is widely abducted at the time of injury it may be dislocated forwards

FIG 1075

Posterior dislocation of the hip joint showing the typical deformity

FIG 1076

Radiograph of posterior dislocation of the hip joint—the femoral head is on the dorsum ilii

These accidents and particularly accidents on the road have greatly increased the frequency of traumatic dislocation Their violence is in striking contrast with the milder perils of the last generation when every writer emphasised the rarity of this injury The typical accident then described was that of a man who stood with one foot on a river bank and the other on a boat which gradually moved away so that the victim's hips were slowly abducted and one was dislocated forwards Mishaps on river banks have given place to violent crashes on high roads and severe crushing injuries in coal mines Dislocation of the hip joint is now one of the more common injuries and series of thirty eighty and more than one hundred

final stage of displacement beyond which it can slip no more (Fig 1062) If displacement of such severity can be masked in an antero posterior view how much more easily can it be concealed when slipping has just begun

FIG 1061

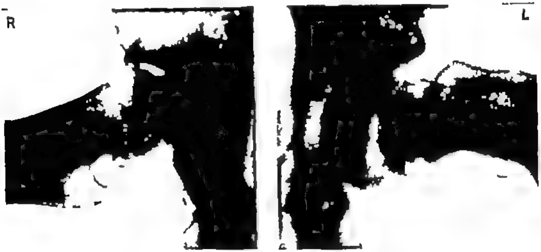

FIG 1062

Same case as that shown in Figure 1060 It is the right upper femoral epiphysis that is displaced (antero-posterior projection Figure 1061 lateral projection Figure 1062) Comparison with the normal left hip which in this particular case is not displaced at all, shows in the antero-posterior projection that the depth of the epiphysis seems to be less than on the normal side; the important point is that the line of the upper margin of the femoral neck projected proximally lies clear of the upper part of the epiphysis, whereas normally it cuts off an appreciable sector In the lateral projection, backward rotation of the epiphysis so that its lower part lies in the digital fossa is even more obvious.

A lateral radiograph should always be taken and without such projection suspected displacement of the upper femoral epiphysis has not been excluded (Figs 1061 1062) In the days before the technique of lateral radiography was perfected a pre-slipping stage was described Only antero posterior

dislocations have been reported by individual surgeons [1-4] Even in children this dislocation is no longer an unusual injury [5-6]

The deformity of a dislocated hip joint—Look at a pelvis from the side and you will see that the antero superior spine acetabulum and tuber ischii form a watershed with the dorsum of the ilium sloping away on one side and the ischio-pubic rami on the other When the head of the femur is displaced it must fall to one or other side of this shed and moreover if it is displaced backwards the femur must be rotated medially and adducted whereas if it is displaced forwards the femur must be rotated laterally and abducted (Figs 1075-1077) Try it with a pelvis and femur

FIG 1077

Anterior dislocation of the hip joint with the head of the femur lying on the obturator foramen and the limb fixed in a typical position of deformity with fixed abduction and therefore relative lengthening.

Dorsal dislocation of the hip joint—*Clinical diagnosis*—The deformity is obvious Since the head of the femur lies on the dorsum ilii the limb must be in adduction with medial rotation and true shortening with of course restriction of all movements There should be no difficulty in establishing the diagnosis But although the clinical signs are obvious there remains the important decision as to whether or not the acetabulum is fractured and this can be established only by x ray examination

Martin, E. "Twenty-nine Cases of Traumatic Dislocation of the Hip." *Lyon chir.*, 1936, 33, 539
Armstrong, J R "Traumatic Dislocation of the Hip-joint Review of One Hundred and One Dislocations." *J Bone Joint Surg* 1948 30-B, 430.
P m, B "Traumatic Dislocations of Hip—Results in Seventy-six Cases" *Acta orthop. scand.*, 19,0, 21, 99
Nicoll, E. Traumatic Dislocation of the Hip—Review of 148 Cases." *J. Bone Joint Surg.*, 1952, 34-B, 503.
Choyce C C Dislocation of Hip—Fifty Reported Cases in Children." *Brit. J Surg* 1924 12, 6..
Clarke H O "Dislocation of the Hip in a Child. *Brit J Surg* 1929 16, 690.

radiographs were available and it was thought that certain signs could be elicited which indicated that slipping was about to take place There is no such stage, if lateral radiographs had been taken at that time it would have been obvious that the epiphysis was already displaced

Failure to take lateral radiographs during treatment may cause still more trouble An upper femoral epiphysis with gross displacement can be made to appear to be perfectly reduced by taking antero-posterior radiographs with the limb in medial rotation (Figs 1063-1066) The position of the epiphysis in relation to the femoral neck has not changed at all and yet 30 degrees of medial rotation gives an appearance of complete reduction and with still more medial rotation the displacement may even appear to be over reduced [1-4] This illusion has caused the destruction of many hip joints It was believed that forcible medial rotation would correct the displacement of an upper femoral epiphysis and radiographs seemed to confirm the success of the manœuvre but several months later after removal of the plaster the original displacement was shown once more. It was thought that the plaster had been removed too soon with late redisplacement The manipulation was therefore repeated a second or even a third time Throughout these months of treatment the position of the epiphysis remained unchanged and the only effect of the manipulations, and of immobilisaton in a strained position of full medial rotation was to stretch the blood vessels of the capsule and ligamentum teres thus causing avascular necrosis with disintegration of the epiphysis and degeneration of the articular cartilage It is obvious that every stage in the diagnosis and treatment of displacement of the upper femoral epiphysis must be controlled by radiographic examination in the lateral plane

Technique of lateral radiography—The limb should be flexed, abducted and laterally rotated [5] With the x ray tube centred in the ordinary way and a casette behind the hip a lateral projection of the femoral head and neck is secured It is usually wise to put the patient in the lithotomy position so that the upper ends of both femora are seen in lateral projection on one film

Early radiographic signs—The first sign is the evidence in the lateral view that the cup-shaped epiphysis is no longer fitting accurately on the curved surface of the metaphysis part of the metaphysis is uncovered in front and a beak of the epiphysis projects behind. In antero-posterior projections the depth of the epiphysis seems to be less than in the normal hip The downward displacement is shown in the antero-posterior view if a line is drawn along the upper margin of the femoral neck and projected beyond the epiphysis Normally this line cuts off a fairly large sector of the upper part of the epiphysis and if the whole of the epiphysis lies below it considerable displacement has already occurred

Late radiographic signs—In later stages the displacement is obvious even in antero-posterior radiographs The epiphysis lies well below its normal level and is so much rotated backwards that it is no longer in profile The whole circle of the epiphysial surface is outlined clearly (see Figures 1067 1069 and 1071)

Mau, C *Arch. Orthop. Mech-Ther* 1926, 24, 63 [4] Mau, C. *Dtsch. Z Chir.*, 1936, 248, 214.
Mau, C Frühdiagnose epiphyseolysis capitis femoris. *Soc Internat. Chir Orth.*, 1937
Waldenström, H "Epiphyseolysis capitis femoris. *Acta chir scand.*, 1930, 67 936 and 1934, 75, 1..
Clark, K. C. "Positioning in Radiography" page 90, *London* Wm. *Heinemann Ltd.*, 1939.

Radiographic diagnosis—There may be detachment of a small fragment from the postero-superior margin of the acetabulum which remains held to the neck of the femur by the joint capsule and is replaced accurately when the dislocation is reduced by manipulation. On the other hand there may be a fracture of a much larger fragment from the back of the acetabulum which tilts out of position and demands operative reduction. Furthermore this fracture is sometimes complicated by paralysis of the sciatic nerve and operative replacement is then needed urgently almost as an emergency procedure.

Reduction of dislocations of the hip—The classical method of reduction of dislocation of the hip joint was first described by Jacob Bigelow of Boston. When he was still a young man at the Massachusetts General Hospital he established his reputation for skill in the correction of this displacement. On one occasion he reduced a dislocation in the Casualty Department and, shortly thereafter having been reproved for side-tracking his chief's cases, he obligingly redislocated the joint and sent the patient up to the wards only to be called upon later to reduce it once again because his chief had failed. His method depended on circumducting the limb through the opposite

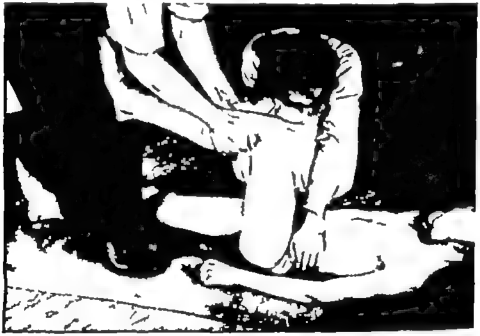

FIG 1078

Manipulative reduction of traumatic dislocation of the hip. The limb is turned into neutral rotation and the femoral head is then quite gently lifted into the acetabulum.

position of deformity into the neutral position. In a posterior dislocation in which the hip was adducted and medially rotated the limb was flexed, abducted *laterally rotated and then* brought down into extension and neutral rotation. Anterior dislocations were reduced in the opposite direction the abducted laterally rotated limb was flexed adducted, medially rotated and finally extended. But this procedure is quite likely to convert an anterior dislocation into a posterior dislocation or a posterior

FIG 1063
Antero-posterior projection in lateral rotation.

FIG 1064
Antero-posterior projection in medial rotation.

FIG 1065
Lateral projection in lateral rotation.

FIG. 1066
Lateral projection in medial rotation

Concealment of epiphysial displacement by medial rotation of the hip joint, giving a false appearance of reduction.

Figure 1063 shows an obviously displaced upper femoral epiphysis. After medial rotation of the hip joint the displacement appears to have been reduced (Fig 1064). Actually the position has not changed the displacement is simply concealed in the antero-posterior view; but it has appeared in the lateral view (Fig 1066), whereas previously it was concealed in the lateral view (Fig 1063).

dislocation into an anterior dislocation Examination of the watershed ' from the anterior iliac spine to the tuber ischii makes it obvious how this can happen In posterior dislocations circumduction of the limb from its position of medial rotation to that of lateral rotation may easily swing the femoral head from behind the joint right past the notch below the acetabulum to the front of the joint Similarly in anterior dislocations circumduction in the opposite direction may rotate the head from the front of the joint again past the acetabular notch to the back

There is a much easier method of manipulative reduction, and it applies equally to posterior and anterior displacements With the patient lying on blankets on the floor the flexed hip is turned into the neutral position and the femur is then lifted into the acetabulum (Fig 1078) No matter whether the femur is adducted and medially rotated from a dorsal dislocation or abducted and laterally rotated from an anterior dislocation when the hip is turned into the neutral position the head of the femur lies below the acetabulum and is quite gently lifted into it There is no need for forcible traction or violent manipulation

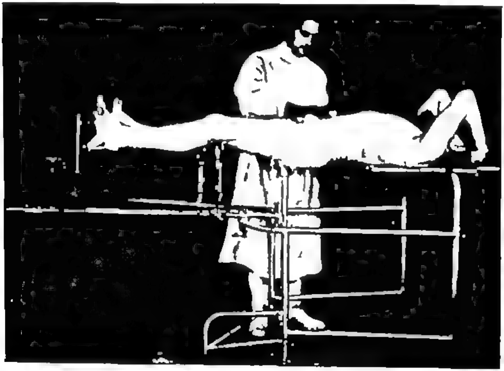

Fig 1079

Application of plaster spica after manipulative reduction of traumatic dislocation of the hip joint.

Immobilisation in a plaster spica—After reduction of the dislocation the joint should of course be immobilised in a plaster spica for six or eight weeks In former years when there was undue emphasis on the apparent stability of the ball-and socket structure of the hip joint without recognition of its weakness in the flexed adducted position the usual after treatment was simply to put the patient to bed for a few days perhaps with the lower limbs lightly bandaged together Recently the proposal that there is no

Treatment of displacements of the upper femoral epiphysis—The treatment of displacements of the upper femoral epiphysis is not a very happy chapter in the history of orthopaedic surgery[1,2]. In former years many hip joints were destroyed by forcible manipulations which were thought to have corrected the displacements but had not corrected them at all (the illusion being sustained only by imperfect radiography). Indeed such manipulations had complicated the situation by causing avascular necrosis with permanent stiffness of the joint and late arthritis[3]. Robert Jones used to say: "Leave them alone; just put them to bed; you will get into less trouble that way." But we have learned much since then and certain principles of treatment have now been defined.

Principles of treatment—The principles of treatment of displacements of the upper femoral epiphysis are: 1) if the epiphysis has begun to displace there can be no safety until the epiphysial line has fused—premature fusion causes little or no disability and moreover it is inevitable; 2) when there is minor displacement the epiphysis should be fused at once by nailing or pinning in the position in which it lies; 3) when there is major displacement it is unwise to correct it forcibly by manipulation under anæsthesia—in recent displacements this is unnecessary and in older displacements it is dangerous; 4) recent major displacements should be corrected by traction and then be stabilised by nailing; 5) older displacements should be corrected by cervical osteotomy and then be stabilised by nailing.

There is no safety until the epiphyseal line has fused—The predisposition to displacement of the upper femoral epiphysis is so strong that it is not enough to correct the displacement; it will almost certainly recur if treatment is abandoned at any time before fusion of the epiphysis is complete. Premature fusion of the epiphysial line is of course inevitable and it is clearly better to make sure that it fuses in the correct position. Such fusion should be secured not by the former crude method of hammering on the trochanter with the object of crushing the epiphysial line[4] nor by the unnecessarily complicated methods of inserting bone grafts[5-7] but by the simple procedure of inserting one or two Moore pins[8] or a three-flanged nail[9] across the epiphysial line (Figs. 1069-1072).

Treatment of minor displacements of the upper femoral epiphysis—If there is clinical and radiographic evidence of early displacement of the upper femoral epiphysis with no more than about 20 degrees limitation of medial rotation movement it is wise to act in advance of the serious displacement that will almost certainly arise and fuse the epiphysis by the insertion of a three-flanged nail or Moore pin. Very commonly this treatment is needed for what might at first seem to be the "normal hip" in a patient who is being treated for severe displacement of the upper femoral epiphysis of the other hip. Although there may have been no symptoms on this side the

Elmslie, R. C. Coxa Vara, its Pathology and Treatment. London 1913.
Scott, W. "Epiphyseolysis of Upper Femur." J. Bone Joint Surg. 1936, 18, 743.
Waldenström, H. "Necrosis of Femoral Epiphysis." Acta chir. scand., 1934, 75, 185.
Jahss, S. A. "Treatment of Pre-slipping Stage of Slipping Upper Femoral Epiphysis" (hammering on the trochanter). J. Bone Joint Surg. 1936, 18, 477.
Ferguson, A. B., and Howorth, M. B. "Slipping Upper Femoral Epiphysis" (multiple drilling of epiphysis with insertion of slivers of bone after arthrotomy). J. Amer. med. Ass., 1931, 97, 1867.
Boman, R. J. "Multiple Drilling of Epiphyseal Plate from Trochanter." J. Bone Joint Surg. 1932, 14, 834.
Mayer, L. "Slipping Femoral Epiphysis" (insertion of tibial bone graft). J. Bone Joint Surg. 1937, 19, 1046.
Moore, A. T. "Fracture of Hip Joint—Treatment by Extra-articular Fixation with Adjustable Nails." Surg. Gyn. Obstet., 1937, 64, 420.
Wilson, P. D. "Slipping Upper Femoral Epiphysis" (insertion of three-flanged nail from trochanter by extra-articular technique). J. Bone Joint Surg. 1938, 20, 379.

need to immobilise a dislocated hip joint after reduction has been revived.[1] I can say only that I have seen many cases in which such after treatment has proved to be very unwise indeed. We recognise the importance of immobilising every other dislocation until tears of ligaments and avulsions of capsule have healed. Why then is it less important to immobilise the torn structures round a dislocated hip? The fact is that it is even more important because in this weight bearing joint failure to protect the injured tissues may cause traumatic subperiosteal ossification, recurrent dislocation, or avascular necrosis of the femoral head. A plaster

FIG. 1080

Dislocation of the hip joint with marginal fracture of the acetabulum after manipulation. Is the dislocation reduced? (Of course it is not reduced—I am almost ashamed to ask you—the femoral head is behind the acetabulum.)

spica with the limb extended in neutral rotation and slight abduction should be kept in position for about six weeks (Fig. 1079). There is no difficulty thereafter in quickly regaining full movement of the knee joint and full power in the muscles of the thigh and hip.

Errors from misinterpretation of the post reduction radiograph—Errors often arise in the treatment of dislocations of the hip joint from misinterpretation of radiographs. After manipulation of a dorsal dislocation

[1] Paus, B. "Traumatic Dislocations of the Hip. Late Results in Seventy-six Cases." *Acta Orth. Scand.* 1951, 21, 99. In advocating only a short period of immobilisation this author has seriously misquoted me as advising for the routine after-treatment of all such dislocations a hip spica for two months with subsequent non-weight-bearing for six months. Anyone who has carefully read my earlier texts knows that this is advised only when there is proved evidence of avascular necrosis. The routine after-treatment I advise is plaster spica for six or eight weeks in uncomplicated dislocations, and for a rather longer period in fracture-dislocations, with immediate weight-bearing thereafter. It seems a pity that advocacy should lead itself to such misquotation.

epiphysis should be pinned or nailed if radiographs show early slipping (Figs 1071 1072 left hip)

Forcible correction by manipulation under anæsthesia is inadvisable—Major displacements have sometimes been reduced successfully by forcible medial rotation and abduction of the limb under anæsthesia—but this is a dangerous manœuvre If the displacement is in fact so acute that it was sustained only two or three days before the manipulation will of course succeed but it will be no more successful than by gentle traction from skin tapes (Figs 1067 1068) If on the other hand the displacement has been occurring gradually over several months such manipulation stretches the capsular vessels and causes avascular necrosis of the epiphysis It is exactly this

Fig 1067

Fig 1068

Displacement of the upper femoral epiphysis before and after reduction by gradual traction on a frame. Note the premature fusion of the epiphysis which in this case occurred even without surgical intervention Such early fusion is inevitable and should be promoted when the displacement has been corrected, if necessary by pinning or nailing (see Figs. 1069 1072).

treatment that was responsible for so many of our disappointments in former years In recent displacements forcible manipulative reduction is no better than gentler methods in older displacements it is positively harmful why then perpetuate it ? Let us abandon forcible manipulation in the treatment of displacements of the upper femoral epiphysis

Treatment of major displacements of the upper femoral epiphysis—If the clinical history and the radiographic evidence suggest that epiphysial displacement is recent reduction should be attempted by simple traction Skin traction from adhesive tapes is all that is needed and it matters not whether this is done by balanced traction with weights traction on a frame or Pugh s traction from the foot of the bed There is no need to force the position or to insist on wide abduction even traction in the adducted position will often succeed [1] It will be evident within a week or two

[1] Wardle E. N "Slipped Epiphysis of the Head of the Femur" (advocating reduction by traction with the hip in the adducted position) *Brit J Surg* 1933 21 313.

in which the femoral head was obviously riding up on the ilium well above the hip joint it may appear that replacement has been effected with the femoral head at its normal level—and yet the joint may still be in a position of complete backward dislocation Figure 1080 is one of the many examples I have seen This had been accepted as a satisfactory reduction but is the dislocation in fact reduced? The head of the femur is no longer on the dorsum ilii it is at the joint level and the outline of femoral head and acetabulum coincide more or less, but the fact is that the head of the femur is lying entirely behind the acetabulum and the appearance of successful reduction arises only from fairly accurate superimposition of the shadows of the dislocated head and the acetabulum In this particular case the superimposition is not quite accurate Shenton's line is broken—that is to say the continuation of the curved line of the lower margin of the superior ramus of the pubis lies well below the curved line of the lower end of the neck of the femur with which it should be continuous This in itself is enough The dislocation is not reduced Sometimes the shadows coincide even more accurately and there may be little or no break in the continuity of Shenton's line But there is still clear radiographic evidence even in antero-posterior projections in the disappearance of the lesser trochanter The shadow of the trochanter becomes smaller as the hip joint is rotated inwards but within the normal range of medial rotation of the joint it never disappears entirely If it has disappeared it means that the hip joint is rotated inwards so fully that the femoral head is behind the acetabulum Failure of reduction may of course be confirmed with even greater certainty by taking lateral radiographs of the joint It should also be obvious from the clinical evidence of persistent medial rotation deformity with restriction of all movements

Fracture-dislocation of the hip joint—When dorsal dislocation of the hip joint is associated with a posterior marginal fracture of the acetabulum the fragment is usually held close to the head of the femur by fibres of joint capsule so that it is replaced accurately when the dislocation is reduced Occasionally a larger fragment is detached from the acetabular margin and tilted outwards so that operative reduction is needed. In about 7 per cent of these fracture-dislocations the sciatic nerve is impaled by the sharp margin of the acetabular fragment and if the pressure is not relieved promptly paralysis may remain permanently Thus the treatment of dislocations of the hip joint with fracture of the margin of the acetabulum resolves itself into three groups of cases 1) In most such fracture dislocations the acetabular fragment is replaced when the dislocated joint is reduced by manipulation, and if this is confirmed by radiographic examination the treatment should be the same as for uncomplicated dislocations 2) If a large acetabular fragment is not replaced by such manipulation the joint should be exposed through a posterior incision the fragment being replaced and fixed in position by a single screw (Figs 1081 1082) 3) If there is fracture-dislocation with sciatic palsy and the acetabular fragment remains tilted after manipulative reduction the back of the joint and the sciatic nerve trunk should be exposed through a posterior incision as an emergency procedure—certainly within twenty four hours—the nerve being gently freed from the bone fragment which is then replaced and fixed with a screw

FIG 1069
Displacement of the upper femoral epiphysis before treatment

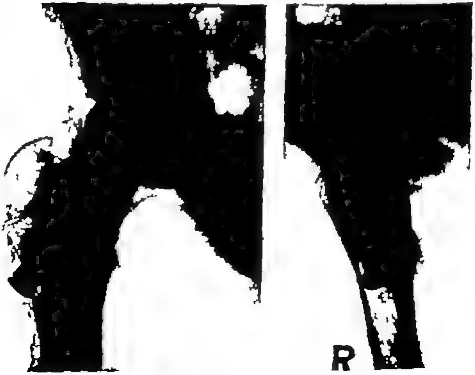

FIG 1070
Same case as Figure 1069 after the displacement ha been reduced by traction, and redisplacement prevented by the insertion of a three-flanged nail. The epiphysial line was not exposed the nail was driven over a guide-wire inserted from the trochanter under radiographic control

Fig 1031

Dorsal dislocation of the hip joint. After manipulative reduction it is obvious from radiographic examination (through plaster) that a large acetabular fragment is tilted outwards. Four weeks had elapsed since injury before the patient was first seen.

Fig 103[illegible]

The displaced fragment of the acetabulum was replaced through a postero-lateral incision and fixed with a screw. In this case there was no paralysis of the sciatic nerve (but see Figs. 249 250).

FIG 1071

Severe displacement of the right upper femoral epiphysis, with early displacement of the left upper femoral epiphysis.

FIG 1072

Same case as Figure 1071 The epiphysis on the left side was pinned in its slightly displaced position with two Moore pins, external fixation not being used. The displacement on the right side could not be reduced by traction and it was corrected by a curved osteotomy at the epiphyseal level, with fixation by one Moore pin and the support of a plaster spica for two months. (*Mr Philip Vernon's case to whom acknowledgment and thanks are paid.*)

Complications of dislocation of the hip joint—Several of the complications of traumatic dislocation of the hip have already been discussed Traumatic ossification or myositis ossificans may occur if the subperiosteal hæmatoma is scattered by early passive movement of the joint and particularly by

FIG 1083

Dislocation of the hip joint complicated by traumatic subperiosteal ossification ("myositis ossificans") because the hip joint was not immobilised in plaster after reduction and early active and passive movements were encouraged.

forcible manipulations Sciatic paralysis is a complication of fracture-dislocations in which the nerve is impaled by the margin of an acetabular fragment Other complications include traumatic arthritis and avascular necrosis recurrent dislocation and unreduced dislocation

Traumatic arthritis from avascular necrosis after dislocation of the hip—The nutrient vessels of the shaft of the femur extend no higher than the femoral neck and the head of the femur is supplied with blood by vessels entering from the capsule and to a less extent from the ligamentum terres In dislocations of the hip joint both these structures are damaged and

whether or not the correct position has been achieved if it has the reduction should be stabilised by inserting a Moore pin or Smith Petersen nail (Figs 1069 1070)

Treatment of older displacements of the upper femoral epiphysis—It may be obvious from the beginning that displacement of the upper femoral epiphysis is of such long standing that simple traction cannot succeed or on the other hand it may be found that a trial of skin traction has failed. There is then a clear indication for correction of the deformity by cervical osteotomy [1] An anterior approach should be used through an incision extending down from the anterior superior iliac spine between the sartorius and rectus femoris medially and the tensor fasciæ femoris and gluteal muscles laterally (the first Smith Petersen approach—not the later one in which dissection was much wider) [2] Special care should be taken to avoid damage to the capsular vessels the most important of which lie postero-superiorly Correction of the displacement may be secured by an osteotomy with curved gouges at the epiphyseal level The new position is then maintained by a nail or pins driven through the trochanter into the femoral neck and the epiphysis It is by no means an easy operation (Figs 1071 1072)

TRAUMATIC DISLOCATION OF THE HIP JOINT

When the femur is flexed and adducted the stability of the hip joint is impaired because in this position the femoral head is unsupported by the acetabulum and is held in position only by capsule (Figs 1073-1074) It is for this reason that spontaneous dislocation occurs so often in poliomyelitis, cerebral spastic palsy and infective arthritis of the hip joint [3] Paralytic dislocation is not uncommon in poliomyelitis if the flexor and adductor muscles remain active while the extensor and abductor muscles are paralysed—there need be no injury unopposed action of the flexor-adductor group of muscles is enough to dislocate the joint Similarly in cerebral palsy over action of the spastic flexor adductor muscles may cause paralytic dislocation Infective or tuberculous arthritis with uncontrolled flexor adductor spasm causes pathological dislocation In all these conditions the flexed-adducted position of the hip joint allows the muscles to drive the femoral head slowly but surely against the capsule until it is displaced

Similarly a normal hip joint is vulnerable to traumatic dislocation if the femur is driven back while the thigh is flexed and adducted In this position a powerful thrust in the long axis of the limb forces the femoral head through the capsule on to the dorsum of the ilium The injury often occurs in head-on motor collisions and has been described as the dashboard dislocation because the usual victim is the front-seat passenger who is sitting with hips flexed and knees crossed so that the knee which lies nearest the dashboard and sustains the impact is that of the flexed adducted hip [4]

Klein, A Joplin, R J and Reidy J A "Treatment in Cases of Slipped Capital Femoral Epiphysis at the Massachusetts General Hospital" *Arch. Surg* 1952, 65, 651.
Smith-Petersen, M N *J Bone Joint Surg.*, 1949, 30-B, 40
Watson-Jones R "Spontaneous Dislocation of the Hip Joint." *Brit. J Surg* 1926, 14, 36.
Funsten R V Kinser P and Frankel, C J "Dashboard Dislocations of the Hip" *J Bone Joint Surg* 1938 20, 124

if all the blood vessels within them are torn or thrombosed avascular necrosis is inevitable (see pages 80 83) In children immobilisation should be continued in an abduction frame for many months until the epiphysis is fully revascularised excellent functional results may be expected In adults the problem is more difficult If the joint is destroyed by degenerative arthritis whether it is a simple traumatic arthritis or an arthritis arising from avascular necrosis, the alternatives are to arthrodese the joint or to perform an arthroplasty Arthrodesis is difficult because the dead and avascular femoral head does not contribute readily to sound fusion so that fibrous rather than bony ankylosis often occurs It is probably better in most of these cases to perform an arthroplasty The cup arthroplasty of Smith Petersen may be preferred but recent experience suggests that it is better to excise the dead part of the head and replace it with a plastic prosthesis as in the Judet arthroplasty [1,2]

Recurrent dislocation of the hip joint—If a traumatic dislocation of the hip joint is not suitably immobilised in plaster or on a frame recurrent dislocation may arise exactly as it does in any other joint where there is failure of immobilisation of the first dislocation. Such recurrence is of course particularly liable to occur when the margin of the acetabulum is fractured Figures 1084 1085 show the hip joint of a young man aged twenty-eight years Within two weeks of reduction of the dislocation of joint he was allowed to stand and walk, and during the next fortnight the hip gave way and he fell to the ground on six separate occasions There was recurrent dislocation every time that the limb was rotated medially the femur slipped on to the dorsum ilii (Fig 1084) every time that it was rotated laterally the dislocation was spontaneously reduced (Fig 1085) In this case the disability was relieved by immobilising the joint in a plaster spica for ten weeks the marginal fracture united and the dislocation did not recur thereafter But of course the recurrence should never have been allowed to take place in the beginning If the joint had been suitably immobilised after reducing the first dislocation there would not have been recurrent dislocation

Unreduced dislocation of the hip joint—*If a dislocated hip joint is left* unreduced for several months the difficulties of treatment are very great Manipulative reduction is usually impossible and operative reduction involves hazards and perils The femoral head is firmly bound in its displaced position by thick scar tissue It may be tightly wedged in the sciatic notch and the problem of exposing and dislodging it is increased by the proximity of the sciatic nerve which is seldom in a normal position. There is always difficulty in identifying and clearing the acetabulum it is full of scarred capsule and distorted soft tissues with the femoral vessels sometimes unusually close on the inner side Hæmorrhage from exposure of the femur resection of the capsule and clearing the acetabulum is considerable and there may be severe shock Moreover even after successful reduction degenerative arthritis very commonly develops. The troubles are still not over because the femoral head is nearly always avascular and dead so that arthrodesis by the usual technique of denuding the joint surface

[1] Judet, J., and Judet, R. "The Use of an Artificial Femoral Head for Arthroplasty of the Hip-Joint." *J Bone Joint Surg.*, 1950, 32-B, 166.
[2] Judet, R., and Judet, J "Technique and Results with the Acrylic Head Prosthesis." *J Bone Joint Surg* 1952 34-B, 173.

Fig 1084

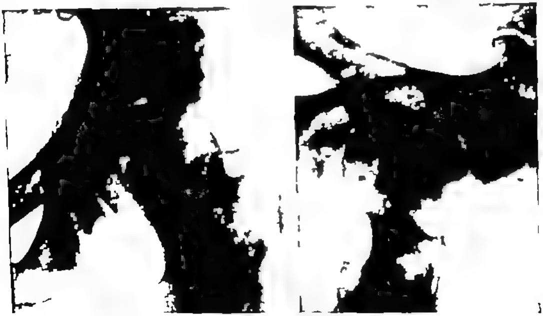

Fig 1085

Recurrent dislocation of the hip joint

Recurrent dislocation of the hip joint due to immobilisation at the time of injury for not more than ten days. Whenever the limb was medially rotated the head of the femur dislocated (Fig 1084), and when the limb was laterally rotated the dislocation was reduced (Fig 1085). The disability was relieved by immobilisation in a plaster spica.

CLASSIFICATION OF FEMORAL NECK FRACTURES

Intracapsular and extracapsular fractures—Fractures of the true neck of the femur should be differentiated from fractures through the base of the neck in the intertrochanteric or pertrochanteric regions The first group which formerly were described as intracapsular fractures are now more commonly recognised as subcapital and transcervical fractures, and the second group once known as extracapsular fractures are now described as inter trochanteric and pertrochanteric fractures (Figs 1102 1104) The clinical differentiation is usually easy because if there is a fracture at the subcapital or transcervical level lateral rotation deformity is limited by the anterior capsule which is still attached to the distal fragment and seldom amounts to more than about 40 degrees whereas when the fracture is in the trochanteric region distal to capsular attachments lateral rotation deformity is limited only when the outer side of the foot lies flat on the bed the deformity then amounting to 90 degrees The level of fracture must of course be confirmed by radiographic examination because the plan of treatment as well as the prognosis differ considerably in the two groups In this section we will discuss subcapital transcervical and low cervical fractures Trochanteric fractures will be considered separately

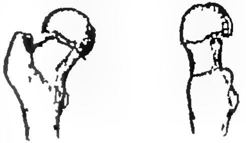

Fig 1102
Abduction fracture
Subcapital—*Intracapsular*

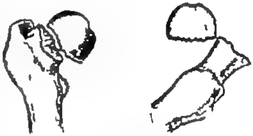

Fig 1103
Adduction fracture
Transcervical—Intracapsular

Fig 1104
Trochanteric fractures
a) Intertrochanteric; *b*) pertrochanteric.
Extracapsular

Impacted abduction fractures and unimpacted adduction fractures—Until recent years a distinction was made between 1) femoral neck fractures at the subcapital level which were impacted on the outer side and were thought to be the result of abduction strains and 2) fractures at the subcapital or transcervical level which were not impacted and were believed to be the consequence of adduction strains[1,2] It seemed that impacted abduction fractures were always in the relatively horizontal plane so that muscle retraction and weight-bearing tended to impact the fragments still more firmly the axis of movement running

[1] [illegible], G "Die Behandlung der frischen medialen Schenkelhalsfrakturen." *Ergeb der Chir und Orthop.*, 1938, 31 607
[2] Waldenström, J "Fractures récentes du Col fémoral—Traitement opératoire ou orthopédique" *Jour de Chir* 1924 24, 129 (Waldenström distinguished a type of fracture which he called the "intermediary fracture"—part way between the impact[illegible]bduction fracture and the non-impacted adduction fracture. It all adds up to the same thing—they ar[illegible] degrees of displacement from the same injury.)

and driving in a three flanged nail will very possibly fail. In one case a second attempt at fusion by ischio femoral arthrodesis also failed. In another patient a two-year old dislocation of the hip was reduced by operation and, three months later arthrodesis with nail was attempted. This failed and five years later because of increasing pain and disability a Judet's arthroplasty was performed. The result twelve months after operation is good but it is probable that in vigorous and relatively young men such plastic prostheses will loosen in the course of years with recurrent pain. My own preference in these exceedingly difficult cases is to perform an operative reduction through a Smith Petersen or postero-lateral approach and fuse the joint either at the same time or at a second-stage operation, with a strong buttress of iliac bone wedged tightly into the pelvis and fixed to the neck and base of the greater trochanter with a single screw together with many iliac bone chips impacted firmly in the joint space and around the main graft. The limb must be immobilised in a double plaster spica for not less than four months and sometimes longer. Only if there is already serious stiffness of the knee joint do I think that early arthroplasty is advisable.

FRACTURE-DISLOCATIONS OF THE HIP JOINT

We have already considered dislocation of the hip joint associated with fracture of the margin of the acetabulum and must now discuss dislocations of the hip with fractures of the same femur—fractures of the femoral head, fractures of the femoral neck, separations of the upper femoral epiphysis and fractures of the shaft of the femur. In 1934 these fracture-dislocations were reviewed by Henry and Bayumi.[1] At that time there were case reports in the literature of thirteen dislocations with marginal fracture of the femoral head, sixteen dislocations with fracture of the neck of the femur and sixteen dislocations with fracture of the shaft of the femur, but very many more have been dealt with since then—and we now have better methods of treatment for these difficult injuries.

Dislocation of the hip joint with fracture of the femoral head—As the head of the femur is driven out of the acetabulum a marginal sector may be sliced from it. The dislocation should be treated in the usual way and it will sometimes be found that the detached fragment has been replaced in a sufficiently accurate position, but if this is not so the fragment must be exposed and excised. The prognosis in this particular fracture-dislocation, occurring in a weight bearing joint, can never be very good because even uncomplicated dislocations often cause late traumatic arthritis and if the articular surface of the femoral head is roughened by the callus of union of a fracture of one sector of the head the risk of arthritis must obviously be increased. Unlike marginal fractures of the acetabulum such fragments cannot be replaced and screwed in position by an extra-articular approach. Thus if manipulative reduction fails to replace the fragment accurately the surgeon should excise it, at the same time preparing for the later reconstructive surgery that will almost certainly be needed—arthroplasty in elderly patients or arthrodesis in those who are younger.

[1] Henry A. K. and Bayumi M. *Brit. J. Surg.*, 1934, 22, 204.

vertically through the plane of fracture and not transversely across it whereas unimpacted adduction fractures were in the relatively vertical plane and were therefore subject to shearing stress from the transmission of body weight or even the effect of muscle traction Pauwels[1] measured the angle in antero posterior radiographs between the line of fracture and the horizontal line through both anterior superior spines (Figs 1105-1106). On this estimation it was believed that with an angle of 30 degrees or less the fracture would unite safely without immobilisation of any sort that with an angle of from 30 to 70 degrees union could be expected only after successful internal fixation with a nail and that with an angle of from 70 to 90 degrees even operative internal fixation needed the additional support of a bone-graft because the shearing strains were so great

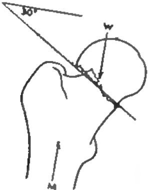

FIG 1105
In the first stage of displacement impaction is usually increased by muscle retraction (M) and even by weight bearing (W).

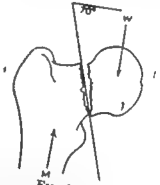

FIG 1106
In the second stage of displacement the forces of muscle retraction and weight bearing shear the fragments.

Further studies especially by Per Linton[2 3] have shown that there is no foundation for this distinction between so-called abduction and adduction fractures of the neck of the femur In each group of fractures the mechanism of injury is the same both arise from lateral rotation strains and the only real distinction to be made is in the degree of displacement When a lateral rotational strain is applied to the lower limb and transmitted to the femoral neck the bone is broken by a rotational force at or near the subcapital level. The plane of fracture is not strictly transverse—it is more nearly spiral the proximal fragment including the femoral head together with a large beak of bone from the back of the femoral neck Figure 1107 shows a femoral head excised in a patient with a recent fracture of the femoral neck there can be no doubt that it was a spiral fracture (see also Per Linton's case in Figure 1108) In the first degree of displacement the fragments are impacted and the plane of fracture seems to be horizontal but as the rotational force continues the impaction is broken up the fragments separate and the plane of fracture seems more vertical But in fact the plane of fracture has been the same from the beginning

1 Pauwels F "Der Schenkelhalsbruch ein mechanisches Problem." Stuttgart Enke 1935.
2 Linton P "On the Different Types of Intracapsular Fracture of the Femoral Neck." Acta chir Scand 1944 90 Supplement 86
3 Linton P "Types of Displacement in Fractures of the Femoral Neck." J Bone Joint Surg 1949 31 B 184

Fig 1086

Fig 1087

Fig 1088

Fig 1089

Dislocation of the hip joint with fracture of the head of the femur Originally it was a posterior dislocation with the fragment displaced below the head (Fig 1086), but attempted manipulative reduction converted it into an anterior dislocation with the marginal fragment above the head (Fig 1087). A second manipulation reduced the dislocation, but with the fragment upside down in the joint (Fig 1088). The fragment was excised, but the joint remained stiff and painful (Fig. 1089)

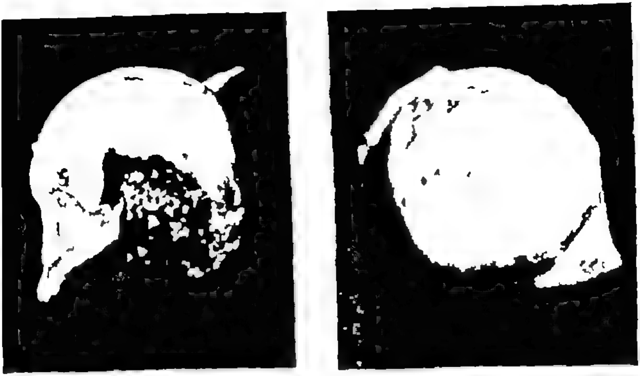

Fig 1107

Head of the femur excised and replaced by plastic prosthesis after a recent subcapital fracture of the femoral neck. Note that the plane of fracture is not transverse it is much more nearly spiral. Note also, in the other view the degenerative change in the articular cartilage which is one reason why this fracture should sometimes be treated in elderly patients by excision and replacement of the femoral head.

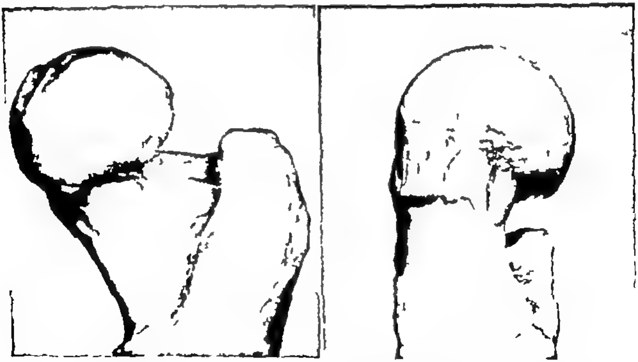

Fig 1108

This is an impacted abduction fracture Note that it is a spiral rotational injury In some radiographic projections the plane of fracture appears to be horizontal but in others it appears to be vertical (*Per Linton, Journal of Bone and Joint Surgery 1949 31-B, 187 by kind permission which has been sought and granted.*)

Dislocation of the hip joint with fracture of the femoral neck—Traumatic dislocation of the hip joint is seldom complicated by fracture of the femoral neck except in elderly patients in whom it is wise to accept the inevitability of avascular necrosis of the separated head with resulting degenerative arthritis of the hip joint Thus as a rule the surgeon should at once excise the detached head and replace it with a plastic or metal prosthesis the dislocation then being reduced and the limb supported in a position of moderate abduction and neutral rotation for several weeks before active movements of the hip joint are encouraged

Dislocation of the hip joint with displacement of the upper femoral epiphysis—In the corresponding injury of the child, which is a dislocation of the hip joint with separation of the upper femoral epiphysis the displaced

Fig 1090

Fig 1091

Posterior dislocation of the hip joint in a child with separation and displacement of the upper femoral epiphysis which was replaced after operative exposure (Fig 1091). After protection of the joint for several months the early functional result was satisfactory

epiphysis should not be excised even although there is again a risk of vascular embarrassment and possibly late traumatic arthritis I know of only one such case (Figs 1090-1091) The epiphysis was replaced through a short incision and the early functional result was satisfactory

Dislocation of the hip joint with fracture of the shaft of the femur—The manipulative reduction of traumatic dislocation of the hip joint depends essentially on applying traction to the shaft of the femur in various positions of rotation so that by circumduction of the limb the femoral head may be guided into the acetabulum This is obviously impossible if there is also a fracture of the mid shaft of the femur (Fig 1092) Even the Stimson technique of laying the patient prone with his lower limbs hanging over the

These apparently different planes in abduction fractures and adduction fractures of the neck of the femur represent no more than the radiographic appearances of varying degrees of displacement of the same rotational injury. Moreover the term "impacted fracture" implies only that injury has stopped short after the first stage of displacement in response to a force which, if continued, would have produced a displaced fracture.[1] It is true that the first stage of displacement represented by an impacted fracture of the femoral neck is relatively safe and seldom needs the internal fixation of a nail, but there is no absolute safety. Per Linton reported one such fracture, treated by recumbency in bed, in which complete displacement developed while the

FIG 1109

FIG 1110

A fracture of the femoral neck which appeared to be impacted "in abduction" (Fig 1109) was treated by simple bed rest. It soon became a typical "adduction" fracture with displacement, and an apparently vertical plane of fracture (Fig. 1110). (Per Linton, "Journal of Bone and Joint Surgery," 1949, 31 B, 186, reproduced by his permission).

patient was under observation (Figs 1109, 1110). Note in these radiographs how the apparently horizontal plane of fracture in the first stage of displacement became an obviously vertical plane of fracture in the second stage of displacement. It is a good example of the radiographic illusion which can be so misleading.

Proposed classification of cervical fractures of the femur.—I suggest that four types of subcapital transcervical or low cervical fracture of the femoral neck should be distinguished, differing only in the degree of displacement but being related closely to the age of the patient, the strength or porosity of the bone and the treatment needed: 1) fractures in children without displacement; 2) fractures in middle aged patients with the first degree of displacement and impaction; 3) fractures in elderly patients whose bones are porotic so that there is more complete displacement; 4) fractures in young adults from severe violence in which a fragment of the femoral neck is driven through the torn anterior capsule.

[1] ... this applies not only to fractures of the neck of the femur but to all ... the ... may occur.

end of a table so that the femoral head might be pushed down into the acetabulum of the prone patient instead of being lifted up into the acetabulum

FIG 109*

Fracture-dislocation of the hip joint. There is a dorsal dislocation of the hip joint with fracture of the upper shaft of the femur; but in addition there is a marginal fracture of the head of the femur the detached fragment lying on the posterior lip of the acetabulum This unusual case therefore demonstrates two of the three rare types of fracture-dislocation.

of a supine patient is far too uncertain and hazardous It is better to acknowledge at once that the fracture of the femoral shaft should first be reduced and immobilised by internal fixation preferably by intramedullary nailing after which there is relatively little difficulty in reducing the

Fractures of the femoral neck in children—The fracture is usually at a low transcervical level almost at the base of the *neck of the femur* (Figs 1111 1112) There is seldom displacement and if the limb is supported in a plaster spica for six or eight weeks the fracture unites soundly It must be recognised however that this fracture in children is often complicated by interruption of blood supply to the femoral head—a complication that occurs in children even more frequently than when similar fractures are sustained by adults[1] The consequent avascular necrosis of the femoral head causes changes in the bone similar to those of Legg Perthes' disease (page 72 of the first volume Figs 143 144) and weight bearing should be

Fig 1111 Fig 1112

Fractures of the neck of the femur in children. They usually occur at a very low transcervical level. There is seldom displacement They unite safely after simple immobilisation in a plaster spica. But there is a surprisingly high incidence of avascular necrosis of the femoral head with changes similar to those of Legg Perthes disease, necessitating long recumbency (*These two cases were treated by Mr W Lawrence of Brighton formerly of the Robert Jones and Agnes Hunt Orthopaedic Hospital to whom acknowledgment is made*)

deferred for about two years until the epiphysis has revascularised and regenerated because otherwise the dead bone will be crushed and coxa plana with degenerative osteoarthritis will develop after ten or twenty years

Fractures of the femoral neck in middle-aged patients—Patients aged from forty to sixty years whose bones do not yet show evidence of senile osteoporosis may sustain a fracture of the femoral neck with the first degree of displacement The fragments are not separated from each other and there is posterior impaction the antero-posterior radiograph suggesting a relatively horizontal plane of fracture and the lateral radiograph proving that there

[1] Seddon, H J "Necrosis of the Head of the Femur following Fracture in a Child" *Proc Roy Soc Med* (Section of Orthopaedics), 1936-37, 30, 10
Nacerra, A. "Necrosis of the Epiphysis after Collum Femoris Fracture." *Acta chir scand* 1937 80, 234.

Fig 1093

Fig 1094

Posterior dislocation of the hip joint with comminuted fracture of the shaft of the same femur treated by open reduction and intramedullary nailing of the fractured shaft of the femur; after that reduction of the dislocated hip and the management thereafter presented relatively little difficulty (see also Figs. 1095-1096)

dislocated femoral head and protecting the injured hip joint. The best example I know of such management of a dislocated hip with fracture of the shaft of the same femur was in a patient I saw in New York who had also sustained a difficult comminuted fracture of the shaft of the other femur On the side of the fracture-dislocation the comminuted fracture of the femoral shaft was first reduced by open operation through an anterior Henry approach and after the reduced fracture had been immobilised by intramedullary nailing the dislocation of the hip joint was reduced by closed manipulation (Figs 1093 1094) The comminuted fracture of the shaft of the femur on the opposite side was then also reduced by open operation and immobilised by intramedullary nailing (Figs 1095-1096) An excellent

FIG. 1113

Antero-posterior and lateral radiographs of subcapital fracture in middle-aged patient with the first degree of displacement. There is impaction " in abduction. The fragments are not completely separated and if it is protected carefully by bed rest the fracture should unite without immobilisation in a plaster spica or splints, and without a nailing operation.

FIG. 1114

Recent subcapital lateral fracture. The femoral neck is foreshortened by rotation deformity. The fracture is in the vertical plane; internal fixation is essential.

FIG. 1115

Old subcapital fracture. Failure of immobilisation of the fragments has caused complete absorption and disappearance of the neck of the femur

Fig 1005

Fig 1006

The same patient whose fracture-dislocation of the right thigh is shown in Figures 1003-1004 had also sustained a comminuted fracture of the shaft of the left femur which was also nailed. A brilliant result was achieved by Dr Preston Wade and Dr Harrison McLoughlin of New York, to whom I am grateful for permission to report this case.

result had been secured by my friends Preston Wade and Harrison McLoughlin

Central fracture-dislocation of the hip joint—It has already been pointed out that a violent thrust in the line of the shaft of the femur in its neutral or slightly abducted position may drive the head of the femur through the floor of the acetabulum. Sometimes this central dislocation is caused by a fall or blow on the trochanteric region of the hip driving the femur upwards and inwards. The essential fractures underlying this central displacement of the femoral head are at the upper and lower limits of the ischium—at its upper end where it fuses with the ilium in the roof of the acetabulum and at its lower end where it joins in the ischio-pubic ramus. There may of

is indeed impaction with no separation of the fragments (Fig 1113) This is the type of fracture that at first may pass unrecognised because there is little or no deformity The patient can still move the limb actively, and may even be able to walk with only slight discomfort There is seldom need for any operation and the protection of splints or plaster is usually unnecessary Almost certainly the fracture will unite soundly if it is protected from further strains But this injury should be recognised as the first stage of a displaced fracture and complete bed rest should be insisted upon for about six weeks It is usually wise to arrange for the wearing of a slipper with a piece of wood nailed to the heel by which to protect the limb from lateral rotation stress (Fig 1135) It should also be recognised that in so far as this is indeed a complete fracture through the subcapital level of the femoral neck the blood supply of the femoral head may have been interrupted and avascular necrosis with degenerative arthritis sometimes develops after two or three years (see page 706 Figs 1137 1139)

Fractures of the femoral neck in elderly patients—In elderly and senile patients the bone of the femoral neck is so porotic that rotational strain usually causes a fracture with complete separation of the fragments so that the limb rotates outwards as far as the intact anterior capsule will allow—about 40 or 50 degrees—the fractured surface of the distal fragment of the neck then facing forwards and lying in front of the femoral head as can be confirmed in lateral radiographs The antero-posterior radiograph shows a fracture in the relatively vertical plane (Fig 1114) Such a fracture cannot unite unless the displacement is reduced and the fragments are protected from shearing and rotational strains

Until thirty years ago nearly every such fracture failed to unite and the bone of the neck of the femur was steadily rubbed away until it disappeared the patient being left with a shortened limb an unstable hip and a Trendelenburg limp which made it essential to use a walking stick or crutch (Fig 1115) Royal Whitman of New York [1] then showed us how to reduce the displacement and immobilise the bone in a plaster spica With such treatment many fractures united—perhaps 40 per cent although until his dying day the indomitable Whitman refused to commit himself to statistics and had therefore to withstand many vigorous and even virulent attacks But his important contribution had been made in proving that these fractures did not present an insoluble problem [2-4] He had shown that if the displacement was reduced and the fragments were properly immobilised the fracture would unite But of course the perils and hazards of plaster spicas in elderly patients were obvious Moreover even perfect plasters with the beautiful polish that Whitman always applied did not suffice to protect the fracture from every rotational or shearing strain especially in fat women so that union was achieved only in about one-third of the patients who survived

Royal Whitman's greatest contribution to surgery was the abduction treatment of fractures of the neck of the femur (*A Surg* 1925, 81 374). His wards in the Hospital for the Ruptured and Crippled, New York, were usually filled with elderly patients immobilised by skilfully applied and beautifully polished plaster spicas, and the "Whitman spica" became a surgical byword. He annoyed his critics by persistent refusal to publish statistics, but he never lost an opportunity of pressing the claims of the abduction treatment, and the principles he established laid the foundation for the modern developments which have solved the problem of the "ununited fracture". After giving up active practice Whitman lived in retirement in England until he died in 1946, his last contribution to this subject being in the *Lancet*, "The Salvaging of Fractures of the Femoral Neck" *Lancet* 1942, 1, 378.

Leadbetter G W "Treatment Fractures Neck of Femur" *J Bone Joint Surg.*, 1933 15, 931.

Leadbetter G W "Closed Reduction Fractures Neck of Femur" *J Bone Joint Surg* 1938, 20, 108.

Cochrane W A "Flexed Plaster Spica for Fractured Femoral Neck." *Lancet* 1941 [illegible] 728.

Fig. 1097

Central dislocation of the hip joint with inward displacement of the floor of the acetabulum. The whole of the ilio-pectineal part of the pelvis is tilted inwards.

Fig. 1098

The head of the femur has been pulled out of the pelvis by skeletal traction but, as often happens, the floor of the acetabulum has failed to follow and is still displaced inwards.

Fig. 1099

The irregularity of the acetabulum caused arthritis necessitating arthrodesis. It may be possible to avoid this by replacement of the pelvic wall through an abdominal incision.

At about this time many attempts were being made to achieve more secure fixation of the reduced fracture by nails screws or pegs. Indeed a

FIG 1116

One of the first successful results in this country of treating a fracture of the neck of the femur by open operative reduction with the insertion of a stainless steel three-flanged nail. Result ten years after operation.

FIG 1117

FIG 1118

Post mortem specimen of a fractured femoral neck ten months after manipulative reduction with insertion of a nail through a short incision below the trochanter under x-ray control of direction. Note that manipulative reduction failed to prevent some capsular interposition in the inferior part of the fracture site but this did not prevent sound union of the greater part of the fractured surfaces. (See also Figure 350 in the first volume—the same case with discussion on the importance of using non-electrolytic non toxic metals.)

nailing technique had been developed as early as 1897 by Nicolaysen[1]. In 1913 Lambotte described the use of two slender nails for internal fixation[2].

[1] Nicolaysen, J. (describing a nailing technique in 1897). *Nord. Med. Ark.*, 189[?] 8, 1.
[2] Lambotte, A. (describing fixation by two nails). "Chirurgie Opératoire des Fractures." Paris: Masson et Cie. 1913.

course be many other lines of fracture with comminution of the floor of the acetabulum

The typical displacement is shown in Figure 1097. The body of the ischium is tilted inwards at its upper end where the plane of fracture enters the acetabulum and outwards at its lower end where there is a fracture through the inferior ischio pubic ramus. Of course the important part of the displacement is that which involves the floor and roof of the acetabulum

It is seldom difficult to pull the head of the femur back to its normal position by skin traction or skeletal traction from a pin in the tibial tubercle but unfortunately the floor of the acetabulum seldom follows the replacement of the femoral head. It is usually wise to accept this position because despite the considerable distortion of the acetabular floor a reasonably good functional result will be secured

Fig 1100

Central dislocation of the hip joint. This is an unusual case in which there is only slight inward displacement of the floor of the pelvis. The bone most displaced is the ilium, which is tilted outwards and dislocated at the sacro iliac joint.

It has been suggested by one or two surgeons that when skin traction on an abduction frame or skeletal tibial traction with a Braun's splint has replaced the femoral head but without accurately reconstructing the floor of the acetabulum the ischium should be exposed from its pelvic aspect through a midline suprapubic incision replaced in accurate position by manual pressure and secured by the insertion of one screw—but there have been no very promising results and there have been several deaths from this surgical adventure. Since the results of simple conservative treatment are always so much better than might be predicted from the radiographic appearances one should be cautious

If traumatic arthritis does develop in later months or years it should usually be dealt with by arthrodesis of the joint (Figs 1095-1097). This injury usually occurs in young healthy men in whom all other joints are normal and sound arthrodesis is therefore to be preferred to the uncertainties of an arthroplasty

Hey Groves tried a four flanged nail [1] but this also failed because electrolytic and toxic reactions to the metal caused surrounding osteoporosis and loosening of the nail It was not until Smith Petersen [2] reintroduced the flanged nail first four flanged and then three flanged at the time that stainless steel and other non-electrolytic and non toxic alloys were discovered, that some success was achieved It was an interesting example of the interrelation of sciences and the dependence of any one upon all others for its advance Smith Petersen would have failed just as surely as Hey Groves failed had it not been for the progress of physicists

At first these three-flanged nails were introduced at the time of an open operation on the fracture itself [2] the capsule of the joint being divided and reflected so as to expose the fractured surfaces (Fig 1116) but soon thereafter methods were developed by which, after closed manipulative reduction of the fracture the nail was introduced through a short incision over the trochanter being guided into its correct position by x ray control in the operating theatre (Figs 1117 1118)

Fig. 1119

Another form of internal fixation of the fractured femoral neck is by four nails placed one in each quadrant of the head of the femur and fixed at the femoral cortex by small threaded nuts. This case was successfully treated by Dr Austin Moore to whom acknowledgments are again made.

Other methods of internal fixation were also developed. A two-flanged nail V-shaped in cross section was used [4] Kirschner wires had been tried but were seldom of sufficient strength [5-6] On the other hand the multiple wire fixation of Austin Moore of Philadelphia [7-10] with four rather stouter

Groves, E. W Hey "On Modern Methods of Treating Fractures." Bristol, John Wright & Sons Ltd., 1916.
Smith-Petersen, M N Cave E. F and Vangorder G W "Intracapsular Fractures of the Neck of the Femur Arch. Surg., 1931 23, 715.
Watson-Jones, R. "Fractures of the Neck of the Femur" Brit J Surg., 1936, 23, 787
Cubbins, W R., Callahan, J J., Scuderi, C. S. Surg Gyn Obstet., 1939 68, 87
Plummer W W "Mechanical Inadequacy of Kirschner Wire in Fractures of the Femoral Neck." J Bone Joint Surg 1938 20, 100.
Sellz, L. "Objections to Kirschner Wire for Femoral Neck Fractures." J Bone Joint Surg., 1939, 21, 162.
Moore Austin. "Skeletal Fixation of Fracture of Hip." J.M C and Ass., 1934 30, 199
Moore Austin. "Extra-articular Fixation Hip with Adjustable Nails. Surg Gyn Obstet., 1937 64 420.
Telson, D R., and Ransohoff N S. "Fixation of the Neck of the Femur with Steel Wires." J Bone Joint Surg 1935 17 27
[10] Gaenslen, F J "Multiple Spik Fixation of Fractures of the Neck of the Femur J Bone Joint Surg., 1935 17 730.

FRACTURES OF THE NECK OF THE FEMUR

Fractures of the neck of the femur are usually sustained by elderly women from *trivial strains such as tripping on a stair or stumbling on a carpet* but they may occur at any age in patients of either sex. It is sometimes possible for the patient to move the hip or even to walk despite the injury and such ordinary signs of fracture as shortening of the limb *seldom develop until after several days or weeks* Quite often the only clinical sign that is obvious is slight lateral rotation deformity and a provisional diagnosis should be made on this evidence alone (Fig 1101). Every elderly patient who after injury complains of pain in the region of the hip and lies with the limb in lateral rotation should be assumed to have sustained a fracture of the femoral neck until radiographs taken in two planes prove otherwise

Fig 1101
Intracapsular fracture of the neck of the femur with typical lateral rotation deformity

In former years this fracture was often a terminal event in the lives of feeble and fragile individuals who died within ten or fourteen days from cardiac, pulmonary or renal complications, aggravated by the enforced recumbency and immobility that was so often permitted Active treatment was often withheld for as long as three or four weeks because it was believed that attempts to immobilise the limb by splints plaster or operative internal fixation would in themselves prove fatal. But considerable advances have been made since then and it is now recognised that internal fixation of the fracture or reconstruction of the joint within the first few days after injury is often vitally important in order to permit early mobilisation and thus avoid the dangers of prolonged recumbency and immobility in senile patients Even in those who are eighty ninety or even more than ninety years of age operative treatment usually succeeds in avoiding fatal complications and in restoring a useful and painless hip [1-4] A short expectation of life does not justify the miseries of an un united fracture—the old have as much right to live in comfort as the young—and the fact is that old people tolerate anæsthesia and surgical intervention extremely well [5]

King, T almost twenty years ago was able to report sixteen operations on patients between the ages of eighty *and ninety-eight years with only two deaths, and his recent figures must show far greater safety than that.* *Brit J Surg.*, 1939, 26, 722.
Watson-Jones, R. My own series of primary nailing of recent fracture of the femoral neck, and reconstruction after primary excision of the femoral head in the last ten years includes very many patients of more than eighty years of age, and two of more than ninety years, without a death.
Metcalfe R. H , Evans, E. M Bonnin, J G., Wyman, J B., Gavey, C. J., Vaughan-Jackson, O J Shere, K. L., Strange, F St C. "Symposium on Problems of Fractures in the Aged. *Proc. Roy Soc Med* 1953, 46, 106.
Van Demmark, O E., and Van Demmark, R. E. "Hip Nailing in Patients of Eighty Years or Older Experiences in One Hundred and Four Consecutive Personal Cases." *Amer J. Surg* 1953, 85, 661.
Wyman, J B Part of a Symposium on Fractures in the A dealing with the Problems of Anaesthesia *Proc Roy Soc Med.* 1953 46, 110.

pins driven into the four quadrants of the femoral head and small thr nuts at the femoral cortex to stop them wandering in the bone was succ although rather more complicated than the central incision of a single (Fig 1119) Putti of Bologna [1] Henderson of the Mayo Clinic [2] Go Moreira of Sao Paulo [3-4] and others used different forms of screw stud b or lag screw with an over threaded sleeve so that the fragments could pulled together and impacted more securely (Fig 1120) Moreover bo grafts especially the whole thickness of the fibula, had often succeed even in earlier years (Fig 1121) and with the new proof of success of th three flanged nail methods of combined grafting of the fibula with nailin of the bone were developed by King of Australia [5] for fractures that were several weeks old when treatment was begun and especially for fractures which seemed to be in the relatively vertical plane (Figs 1122 1123)

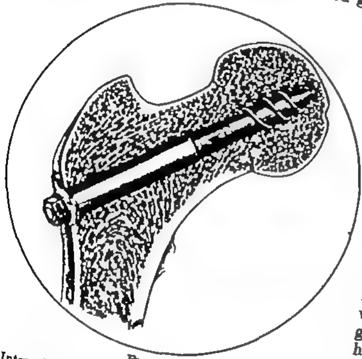

Fig 1120

Internal fixation of fractured femoral neck by lag screw After the main wide thread screw has been inserted, a threaded sleeve together with a nut and bolt at the trochanteric cortex tightens the bone fragments together and impacts them (Putti, Henderson, Ottolenghi, and others).

All these procedure were of course simpl variants of the same principle of reducing the displacement by manipula tion and then securing metallic internal fixation with or without a bone graft in order to avoid the hazards of long periods of immobilisation in plaster They succeeded in securi union of the fracture in high proportion of patients Indeed if the constitution and general resistance of the patient was good enough, the operation skilful enough and the after treatment careful enough there seemed no reason why every such fracture should not unite But there remained one complication beyond the control of the surgeon The blood supply to the femoral head from capsular vessels running in retinaculæ close to the bone is often cut off by the fracture In these circumstances avascular necrosis of the femoral head always causes delay in union and often giv rise to painful degenerative arthritis within a few years so that despite al operative skill perfect functional results from the nailing operation were secured in no more than about two-thirds of the cases

[1] Putti V ... tion of Fracture Neck of Femur Chir Organi Mov., 1939 23, 399
[2] Henderson M ... Proc Mayo Clin 1936, 2, 573 Arch Surg 1937 35, 419; Ann Surg 1938, 107 12
[3] ... Moreira F ... Tratamento Operatorio Fracturas do Collo Femoral." Brasil Med 1938, 52, 116
[4] ... Moreira F ... A Special Stud-bolt Screw J Bone Joint Surg., 1940 22, 663, and 1945, 27 ...
[5] King T ... Closed Operation for Intracapsular Fracture of Neck of the Femur" Brit J Surg 1939, 26, 721

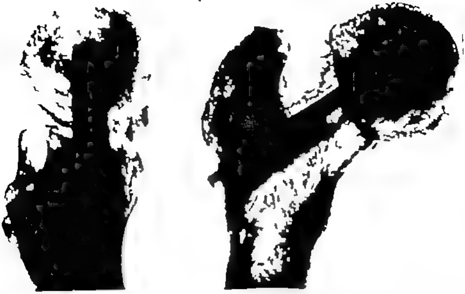

Fig 1121

Recent fracture of the neck of the femur successfully immobilised after manipulative reduction by driving in a graft of the fibula, rather than a three flanged nail, though the patient died two months later from intercurrent disorder (*Treated at the Robert Jones and Agnes Hunt Orthopaedic Hospital by [illegible] now Professor of Orthopaedic Surgery [illegible]*)

Fig 1122

In this case a nail used in the treatment of a fracture of the femoral neck with delayed union was later replaced by a graft of the fibula.

Fig 1123

Combined grafting and nailing may be advisable especially when there has been delay and a fracture of the femoral neck is already several weeks old.

assist the surgeon in placing the guide wire correctly So many different appliances have been invented that any one of about fifty techniques can now be used The literature is abstracted below[120] But long ago I urged that we should discard them all and rely alone on the surgeon s sight and touch controlled by x rays and this is now the general custom

Simple technique of reducing and nailing a fracture of the femoral neck —with guide wires, cannulated nails and x ray control—The fracture must first be reduced This is nearly always easy All that is needed is to take the foot of the injured limb apply gentle traction turn it to the position of neutral rotation and abduct it about 20 degrees A special table should be used such as that shown in Figure 1120 from which all extraneous devices have been removed so as to make it as simple as possible The patient is placed on the pelvic rest and shoulder support The uninjured limb is secured to the foot support on that side and fixed in neutral rotation and about 40 degrees of abduction The surgeon then applies gentle traction to the injured limb turns it into neutral rotation and fixes it on the table in about 20 degrees of abduction with just sufficient traction to keep it taut There is danger of over reduction if too much traction is used and there is always danger in abducting the limb too widely Radiographs in antero posterior and lateral projections should then be taken and the position of the limb is adjusted until the fragments lie in a perfect position

A four or five inch incision is made over the lateral aspect of the thigh centred on the upper shaft of the femur just below the lower margin of the greater trochanter The incision is deepened to bone and the exact lower

Plummer W W "Mechanical Inadequacy of Kirschner Wire in Fractures of the Neck of the Femur *J Bone Joint Surg.*, 1938 20, 100.
Seitz, K. Objections to Kirschner Wire for Femoral Neck Fracture" *J Bone Joint Surg* 1939 21 182.
Johansson, S (Adjustable two-plane screw directing device with spirit level.) *Act orthop scand* 1932, 3, 362. *Brit med J* 1937 2, 201
King, T (Passing preliminary guide by sense of touch along the surface of the neck, and introducing final guide under fluoroscopic control.) *Med J Aust* 1934, 1 5, and 1934, 2, 821.
Westcott, H H (Measuring angle of neck first in X-ray and then on bone by protractor laid on shaft of femur) *J Bone Joint Surg* 1934 16, 372.
Luck J V (Wire laid on skin or passed along anterior surface of neck for preliminary determination of axis in antero-posterior direction.) *J Bone Joint Surg* 1935 17 332.
Gilding, [illegible] L (Long punch handle for more easily controlling direction by eye.) *Brit med J.*, 1936, 1 18.
White, J Warren (Long handle attached to nail to facilitate directing by judgment of eye.) *J Bone Joint Surg* 1935, 17 1065.
Watson-Jones [illegible] (Heavy guide wire first devised for open reduction, now used for simple extra-articular technique see p. 684.) *Brit. J Surg* 1936, 23, 87
Gaenslen, F J (Reduction and nailing with hip flexed 90 degrees in a plaster mould.) *J Amer med Ass.*, 1936, 107 105.
Uecheler E. [illegible] (Insertion of cannula under direct fluoroscopic vision.) *Amer J Surg.*, 1937 n.s. 37 206.
Smith-Petersen, M N (Wescott protractor Warren White handle and direct insertion of nail by judgment of eye.) *Surg Gyn Obstet.*, 1937 64 287
Bailey E. T (Introducer with a cannula which lies in the correct axis if the block of the apparatus is held firmly against the side of the femoral shaft and the blade on the front of the femoral neck.) *Lancet* 1937 1 378.
Groves, E. W Hey (Notched V rod laid on skin for antero-posterior direction and holder with spikes driven through skin on to front of femoral neck for lateral direction) *Brit med J.*, 1947 2, 330 (*N B.*—I have myself perforated the femoral artery with this instrument, the limb fortunately surviving despite femoral ligation.)
Keane D (Modified Hey Groves notched V-rod.) *Surg Gyn Obstet.* 1938, 67 354.
Lloyd, E. I (Adjustable two-plane screw device for direct insertion of nail based on Johansson s instrument but less complicated and even more efficient) *Brit med J* 1938 1 871
Brittain, H A (Michel clips on skin for antero-posterior direction and guide along surface of neck for lateral direction.) *Brit med J* 1938 1 [illegible]
Mumford, F B (Wire laid on skin for antero-posterior direction.) *J Indiana St. med Ass.*, 1938, 31 [illegible]
Rendu A. (Two-plane finder of perforated rods, driven into cortex of femur for radiographic indication of direction of guide) *Arch méd. Lyon* 1938 35, 21[illegible]
Laurel, G C and May H (Two-plane fan-shaped direction finder of radiating cannulæ marked with lead strips) *Surg Gyn Obstet* 1939 68, 40[illegible]. *J Amer med Ass* 1938, 110 18[illegible] (see p. 637)

Fractures of the femoral neck in very elderly patients—Despite the frequency of this complication which cannot be avoided it is still right to treat recent fractures of the femoral neck in patients of fifty, sixty or even more than seventy years of age by the methods of internal fixation described. Even if degenerative arthritis does supervene there is still time to perform reconstructive measures such as arthroplasty with a reasonable prospect of a happy life after that But if the patient is already eighty or ninety years of age it seems hard to propose operative nailing of the fracture and at the same time prepare for the possibilities of another major reconstructive

FIG. 1124

FIG 1125

Recent fracture of the femoral neck in a patient eighty five years of age (note the calcification of the iliac and femoral vessels), treated by primary excision of the femoral head with replacement by a plastic prosthesis, thus anticipating the degenerative osteoarthritis that was likely to arise and planning only one, instead of perhaps two, major operations in so elderly a patient. *(Operation by my colleague Mr Vaughan Jackson, to whom I am grateful.)*

operation within a few years We must wonder whether they will have time to enjoy the results of such a programme of surgery

Thus a strong case can be made out in really old ladies for performing joint reconstruction at the time of the original fracture—excising the femoral head and replacing it with a plastic prosthesis (Figs 1124 1125) In expert hands the operation can be done within thirty or forty minutes and with little or no more disturbance to the patient than if the fracture had been nailed

Fractures of the femoral neck in young adults—Very occasionally a young man of twenty to thirty five years of age may sustain a subcapital or transcervical fracture of the femoral neck from severe violence in which a beak of bone from one fragment is torn through the anterior capsule and gripped by it in such a way that manipulative reduction is impossible Although it is true that open operative reduction of displacement has long

limit of the greater trochanter is identified by seeing the level at which the upper fibres of vastus lateralis disappear and merge with it. Two thirds of an inch below this trochanteric margin is the point on the femoral cortex that coincides with the midline of the femoral neck. Here a small hole one third of an inch in diameter is gouged from the cortex. This is a most important step because without it the guide wire cannot be introduced by

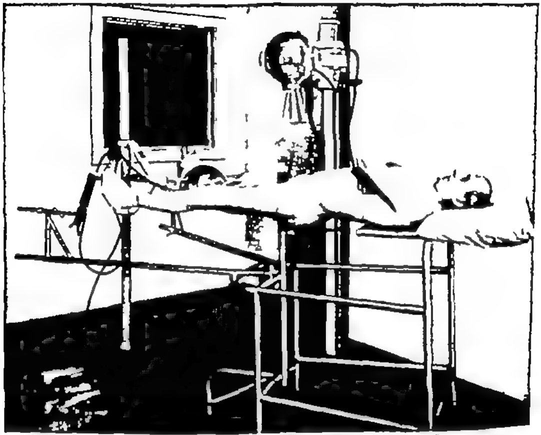

FIG. 11?0

Watson-Jones traction table for operating on the hip under x ... as simple as possible by excluding all extraneous devices. The p... and pelvic rest which ... of radio-translucent material. The ... bandage to the foot rests. Traction can be applied, and any po... of the limbs is possible without int... with radiograph... impor... operation its...

It has been made ... shoulder ... by strap... and ... or ...

been abandoned in the fractures of middle aged and elderly women it may be unavoidable in these rare cases in young men At the time of the open reduction which is sometimes very difficult the fragments should of course be nailed

Summary of the treatment of fractures of the femoral neck in four age groups—We may now summarise the treatment of fractures of the neck of the femur in accordance with the proposed classification into four age groups 1) *in children* the usual low transcervical fracture without displacement should be treated by immobilisation in a plaster spica for about two months 2) *in young adult men* transcervical fractures caused by violence with displacement and capsular interposition should be treated by open operative reduction and the internal fixation of a three-flanged nail 3) *in middle-aged women* subcapital and transcervical fractures with impaction in abduction should be treated by simple bed rest for six weeks—very seldom is a nail needed 4) *in elderly patients* with cervical fractures showing typical displacement manipulative reduction should be followed by the internal fixation of a nail directed by x ray control, 4a) *in very elderly patients* with cervical fractures showing typical displacement it may be wise to excise the femoral head and replace it with a plastic or stainless steel prosthesis

TECHNIQUE OF NAILING FRACTURES OF THE FEMORAL NECK UNDER X-RAY CONTROL

The four essentials of the operation and of the after treatment are 1) the three-flanged nail must be of so exact a length that it is sufficiently buried in the proximal fragment to afford complete fixation and yet not be so far buried as to penetrate the joint surface 2) the nail should be placed almost exactly in the middle of the fragments so that it cannot break out of the head (Fig 1126) 3) loosening of the nail must not occur from infection of the wound or from the use of ionisable or toxic metals and steps should be taken to prevent the nail from sliding out of its track before the fracture is united 4) there should be early protection from weight-bearing but full knee exercises should begin immediately after operation in order to prevent stiffness of the joint

FIG 1126

Marginal insertion of the nail may allow it to break out with a secondary fracture of a small sector of the femoral head.

Use of cannulated nails and guide wires—If a three-flanged nail is driven half way in and then found to be incorrectly placed it is difficult to withdraw it Moreover every time this is done more of the slender bone of the femoral neck is destroyed It is better first to insert guide wires and when radiographs show that one is placed exactly in the correct position

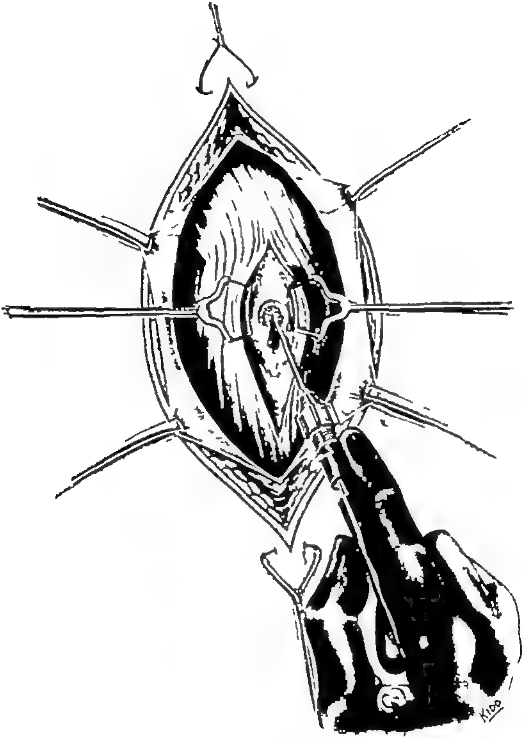

Fig. 1130

Simple technique for extra-articular nailing operation

A hole one third of an inch in diameter is gouged in the femoral cortex in the middle of the lateral surface, just two-thirds of an inch below the lower margin of the greater trochanter—as defined by the upper limit of vastus lateralis. Through this a guide-wire can easily be passed by sense of touch. If by misdirection the point of the wire reaches the cortex of the femoral neck—the front, back, top or bottom—the resistance is obvious. There is slight resistance as the wire passes the fracture line and more firm resistance on reaching the articular surface of the femoral head, usually at a penetration of three and a quarter to three and three-quarter inches.

Fractures of the femoral neck in very elderly patients—Despite the frequency of this complication which cannot be avoided, it is still right to treat recent fractures of the femoral neck in patients of fifty sixty or even more than seventy years of age by the methods of internal fixation described. Even if degenerative arthritis does supervene there is still time to perform reconstructive measures such as arthroplasty with a reasonable prospect of a happy life after that But if the patient is already eighty or ninety years of age it seems hard to propose operative nailing of the fracture and at the same time prepare for the possibilities of another major reconstructive

Fig 1124 Fig. 1125

Recent fracture of the femoral neck in a patient eighty five years of age (note the calcification of the iliac and femoral vessels), treated by primary excision of the femoral head with replacement by a plastic prosthesis, thus anticipating the degenerative osteoarthritis that was likely to arise and planning only one, instead of perhaps two, major operations in so elderly a patient (*Operation by my colleague Mr Vaughan Jackson, to whom I am grateful*)

operation within a few years We must wonder whether they will have time to enjoy the results of such a programme of surgery

Thus a strong case can be made out in really old ladies for performing joint reconstruction at the time of the original fracture—excising the femoral head and replacing it with a plastic prosthesis (Figs 1124-1125) In expert hands the operation can be done within thirty or forty minutes and with little or no more disturbance to the patient than if the fracture had been nailed.

Fractures of the femoral neck in young adults—Very occasionally a young man of twenty to thirty five years of age may sustain a subcapital or transcervical fracture of the femoral neck from severe violence in which a beak of bone from one fragment is torn through the anterior capsule and gripped by it in such a way that manipulative reduction is impossible Although it is true that open operative reduction of displacement has long

cannula of the nail and thus being driven in with it The steps of the operation are shown in radiographs taken in the operating theatre in Figures 1131 to 1134

When the nail has been gently driven in until its head lies flush with the cortex an impactor punch should be hammered cautiously on the trochanter (the punch having a central hole larger than the head of the nail so that the force is applied only to bone) in order to close any gap that may have arisen at the site of fracture as the nail was driven across it If final radiographs show accurate reduction and apposition of the fragments with accurate placing of the nail a small cross pin should be inserted through the head of the nail into the femoral cortex in order to prevent early extrusion (Fig 1134)

The wound is closed in layers and the patient is returned to bed. There is of course no need for splints or plaster but it is wise for the patient to wear a slipper with a piece of wood nailed to the heel so that the limb will not fall into the laterally rotated position (Fig 1135)

FIG 1135

Slipper with cross wood nailed to heel, worn after operation to prevent limb from falling into lateral rotation No other splint necessary

Post-operative treatment after nailing—The day after operation the patient should sit up in bed and move about freely Deep breathing exercises should be practised The knee joint of the injured limb should be moved throughout its full range from the first day At first the patient may find this difficult, but unless initial fear is overcome and movements are practised despite cramp there will be much more difficulty in mobilising the stiff joint in later stages. During exercise periods—hourly throughout the day—the slipper should be removed the patient turning to one side so that the knee can be flexed fully without straining the hip Within two or three weeks the patient may sit up in a chair near the bed But it is unwise to encourage weight bearing until after six or eight weeks Provided that full mobility in bed is encouraged no advantage is gained by early weight bearing and there are of course risks During the first few weeks of weight-bearing activity the patient should have the support of two crutches and then of two sticks. All such aids should be discarded within three or four months

Complications of the operation—The success of every surgical operation depends upon the skill and perseverance of the surgeon and this is certainly true of the operation of nailing a fracture of the neck of the femur Eric Lloyd of London said The bad results of nailing are the results of bad nailing

It seems unprofitable to discuss every complication that has occurred from errors of technique but at the same time it must be emphasised that simple as the operation may have sounded from its description in the last few pages it is indeed charged with every possibility of disaster First there must be perfect asepsis many hip joints have been destroyed by infection. Secondly there must be good theatre radiography in the lateral as well as

the antero posterior plane no surgeon should begin to try to nail the neck of the femur unless he can rely on lateral radiographs Thirdly, there must be attention to every detail of the technique described No longer should there be failures because the guide wire was not accurately inserted, because the nail entered the lateral and not the central part of the head, or because the nail was too long and penetrated the joint or too short and failed to hold the fragments No longer should there be failures because imperfect steel was used so that the nail loosened or failures from early sliding of the nail out of its track because it was not fixed by a cross pin No longer should a guide wire be driven ahead of the nail into the pelvis because it caught in the cannula (Fig 1136) These are complications that should be

Fig 1136

Guide wire caught in cannula of nail and inadvertently driven through the hip joint The difficulties were increased by *fracture of the wire* the central part of which had to be removed by an abdominal approach. *(By courtesy of "Brit Jour Surg" from Author's article* 1930 xvii, 787.)

avoided if attention is paid to every detail of the technique But there will still remain failures from vascular complications which are beyond the control of the surgeon

Complications arising from avascular necrosis of the femoral head—No matter how successful the nailing operation may have been, it is always possible that at the moment of fracture the blood vessels to the femoral head where they lie in retinaculæ running from the capsule to the bone were destroyed by the injury In these circumstances avascular necrosis of the femoral head will develop with consequent degenerative changes If the destruction of blood supply is complete the whole of the proximal half of the femoral head will die—that is to say all that part of the head supplied by capsular vessels which corresponds roughly with the original epiphysis A line of separation between dead bone and living bone develops This has often been *misinterpreted as non union of the fracture itself*

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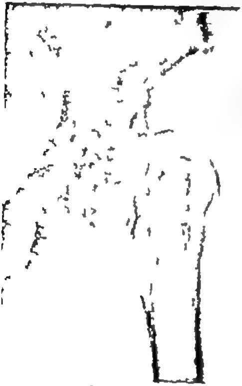

FIG 1124

FIG 1125

Recent fracture of the femoral neck in a patient eighty five years of age (note the calcification of the iliac and femoral vessels), treated by primary excision of the femoral head with replacement by a plastic prosthesis, thus anticipating the degenerative osteoarthritis that was likely to arise and planning only one, instead of perhaps two, major operations in so elderly a patient (*Operation by my colleague Mr Vaughan Jackson, to whom I am grateful*)

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reduction is essential. Failure to do this accounts for the non union of the trochanteric fracture seen in Figure 1145 If manipulative reduction by turning the limb into neutral rotation and slight abduction is proved by radiographs to have failed to secure reasonable apposition of the fragments this possibility of interposition of soft tissues must be considered.

In elderly patients this complication can almost be ignored. It is only in young athletic men whose fractures are sustained from severe violence driving the upper shaft of the femur forcibly through muscle planes that

FIG. 1143

Inter trochanteric fracture of the femur un-united because there was interposition of soft parts between the fractured surfaces These fractures at the inter trochanteric or per trochanteric level almost invariably unite whatever the treatment may be but in rare cases and this is one soft tissue interposition demands open operative reduction.

the problem of non union need even be thought about Even in this rare group of injuries in young men fractures with interposition of soft parts causing non union are nearly always at the subtrochanteric level or sometimes at the lowest part of the femoral neck itself In patients in their eighth ninth or tenth decades of life who sustain trochanteric fractures the treatment is to be resolved in relation to the nursing services that are available If the nursing services are good enough life and limbs can be saved by conservative treatment but otherwise it may be better to perform operative internal fixation as an emergency procedure

been abandoned in the fractures of middle aged and elderly women, it may be unavoidable in these rare cases in young men At the time of the open reduction which is sometimes very difficult the fragments should of course be nailed

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The four essentials of the operation and of the after treatment are 1) the three-flanged nail must be of so exact a length that it is sufficiently buried in the proximal fragment to afford complete fixation and yet not be so far buried as to penetrate the joint surface 2) the nail should be placed almost exactly in the middle of the fragments so that it cannot break out of the head (Fig 1126) 3) loosening of the nail must not occur from infection of the wound, or from the use of ionisable or toxic metals and steps should be taken to prevent the nail from sliding out of its track before the fracture is united 4) there should be early protection from weight-bearing but full knee exercises should begin immediately after operation in order to prevent stiffness of the joint

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UN UNITED FRACTURE OF THE NECK OF THE FEMUR

When a person stands on one leg the opposite side of the pelvis is slightly raised in order to balance the trunk more evenly on the weight bearing limb The line of transmission of weight then passes from the femur through the middle of the acetabulum and sacro iliac joint to the spine (Fig 1146) This tilt of the pelvis accompanies every step of walking at the moment

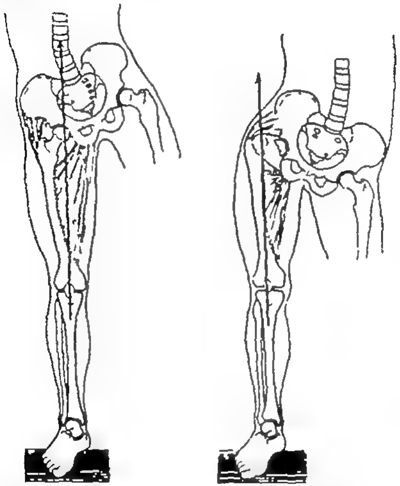

Fig 1146 Fig 1147

The normal line of weight bearing when standing on one leg (Fig 1146) and the line of weight-bearing after non union of a fractured neck of the femur where the pelvis dips on the opposite side and both true and apparent shortening are increased (Fig. 1147).

that one foot is off the ground and it accounts for the *very slight roll* of normal gait a roll which is accentuated in the seafaring man whose activities demand an even more accurate balance If a *patient* with an un united fracture of the neck of the femur tries to stand with all *his* weight on the injured limb the upward lift of the pelvis on the opposite side cannot be maintained There is telescopic instability of the hip, and instead of weight passing directly from the femur to the acetabulum it is taken indirectly by the tension of the gluteal muscles over the trochanter The pelvis therefore drops until these muscles are taut *the opposite side being* lowered and not raised (Fig 1147 Trendelenburg s sign) Both the true

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shortening and the apparent shortening from adduction deformity are increased when weight is borne on the limb The transmission of weight by stretching of the gluteal muscles causes discomfort, aching pain, and hurried movement from the injured to the normal side which with the shortening and pelvic dip, account for a typical limp

The essential object of an operation for non union of a fracture of the neck of the femur is to correct this telescopic instability and promote direct transmission of weight from the femur to the acetabulum pelvis and spine Three types of operation are available the indications depending on the degree of absorption and disappearance of the femoral neck and the vitality of the femoral head

1) When there is minimal absorption of the femoral neck and no evidence of avascular necrosis of the head of the femur the un united fracture should be treated either by an abduction osteotomy by which to produce valgus impaction of the fragments together with the external support of a plaster spica or multiple drilling of the fractured surfaces together with the internal fixation of a nail, or fibular graft or both

2) When there is more absorption of the femoral neck and a likelihood that the head of the femur is dead the un united fracture may be treated by a reconstruction operation of the Whitman Colonna or *Brackett type or by replacement of the femoral head with a plastic or metal prosthesis*

3) When there is some absorption of the femoral neck and uncertainty as to whether or not the head of the femur is dead the safe procedure is to perform a bifurcation osteotomy through the base of the trochanter with inward displacement of the femoral shaft protected either by a plaster spica or by some form of internal fixation

Abduction osteotomy to produce valgus impaction—The purpose of an abduction osteotomy is to turn the shaft from the adducted to the abducted position so that the shearing stress of weight-bearing and muscle retraction becomes an impaction force (pp 30-31 first volume) The operation is therefore applicable to a fracture with delayed union in which final consolidation is prevented by the stresses of adduction deformity but not to a fracture with established non union or to one in which most of the femoral neck has disappeared The osteotomy is performed immediately below the greater trochanter It passes obliquely inwards and downwards, so that when the shaft is abducted its upper end lies in stable apposition with the oblique cut surface of the proximal fragment and cannot displace inwards The degree of correction must be such that the long axis of the femur will pass directly through the fracture and the head of the femur (see inset diagrams Figs 71 74) The angle may be calculated with precision from radiographs and before the bone is divided parallel wires may perhaps be driven in above and below the level of osteotomy so that the correction can be estimated by the angle between the wires. A simpler and equally certain technique is to perform an ordinary osteotomy and apply a plaster spica with the deformity corrected as nearly as possible and two or three days later if radiographs show that the new alignment is not accurate to wedge the plaster under radiographic control by the technique shown in Figures 29 -200 The required alignment can be secured with precision by

assist the surgeon in placing the guide wire correctly So many different appliances have been invented that any one of about fifty techniques can now be used The literature is abstracted below [1-70] But long ago I urged that we should discard them all and rely alone on the surgeon s sight and touch controlled by x rays and this is now the general custom

Simple technique of reducing and nailing a fracture of the femoral neck —with guide wires, cannulated nails and x-ray control—The fracture must first be reduced This is nearly always easy All that is needed is to take the foot of the injured limb apply gentle traction turn it to the position of neutral rotation and abduct it about 20 degrees A special table should be used such as that shown in Figure 1120 from which all extraneous devices have been removed so as to make it as simple as possible The patient is placed on the pelvic rest and shoulder support The uninjured limb is secured to the foot support on that side and fixed in neutral rotation and about 40 degrees of abduction The surgeon then applies gentle traction to the injured limb turns it into neutral rotation and fixes it on the table in about 20 degrees of abduction with just sufficient traction to keep it taut There is danger of over reduction if too much traction is used and there is always danger in abducting the limb too widely Radiographs in antero posterior and lateral projections should then be taken, and the position of the limb is adjusted until the fragments lie in a perfect position

A four or five inch incision is made over the lateral aspect of the thigh centred on the upper shaft of the femur just below the lower margin of the greater trochanter The incision is deepened to bone and the exact lower

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Johansson, S (Adjustable two-plane screw directing device with spirit level.) *Acta orthop scand* 1932, 3, 362. *Brit med J* 1937 2, 361.

King, T (Passing preliminary guide by sense of touch along the surface of the neck, and introducing final guide under fluoroscopic control.) *Med J Aust* 1934 1 8, and 1933 2, 821.

Westcott, H H. (Measuring angle of neck first in X-ray and then on bone by protractor laid on shaft of femur) *J Bone Joint Surg* 1934, 16, 3 ...

Luck, J V (Wire laid on skin or passed along anterior surface of neck for preliminary determination of axis in antero-posterior direction) *J Bone Joint Surg.*, 1935 17 382.

Stirling, R. I. (Long punch handle for more easily controlling direction by eye.) *Brit. med J* 1935 1 18.

White, J Warren. (Long handle attached to nail to facilitate directing by judgment of eye.) *J Bone Joint Surg* 1935, 17 1065.

Watson-Jones, R. (Heavy guide wire first devised for open reduction, now used for simple extra-articular technique see p. 698.) *Brit J Surg* 1936, 23, 787

Gaenslen, F J (Reduction and nailing with hip flexed 90 degrees in a plaster mould.) *J Amer med. Ass.*, 1936, 107 105.

Geckeler E. O (Insertion of cannula under direct fluoroscopic vision.) *Amer J Surg.*, 1937 N.S. 37 396.

Smith-Petersen, M N (Westcott protractor Warren White handle and direct insertion of nail by judgment of eye) *Surg Gyn Obstet.*, 1937 64 287

Bailey E. T (Introducer with a cannula which lies in the correct axis if the block of the apparatus is held firmly against the side of the femoral shaft and the blade on the front of the femoral neck.) *Lancet* 1937 1 375.

Groves, E. W Hey (Notched V rod laid on skin for antero-posterior direction and holder with spikes driven through skin on the front of femoral neck for lateral direction.) *Brit. med J.*, 1937 2, 339 (N B.—I have myself perforated the femoral artery with this instrument, the limb fortunately surviving despite femoral ligation.)

Kane, H (Modified Hey Groves notched V rod.) *Surg Gyn Obstet.* 1938 67 334.

Lloyd, E. I (Adjustable two-plane screw device for direct insertion of nail based on Johansson s instrument but less complicated and even more efficient) *Brit. med J* 1938 1 5 1.

Brittain, H. A. (Michel clips on skin for antero-posterior direction and guide along surface of neck for lateral direction) *Brit med J* 1938 1 773.

Mumford E. B (Wire laid on skin for antero-posterior direction.) *J Indiana St med Ass* 1938, 31, 396.

Rendu, A. (Two-plane finder of perforated rods, driven into cortex of femur for radiographic indication of direction of guide) *Lyon méd.* 1938 35, 249

Engel, G C., and May H. (Two-plane fan-shaped direction finder of radiating cannulæ marked with lead strips.) *Surg Gyn. Obstet.* 1938, 66, 405. *J Amer med Ass.* 1938, 110, 1679 (see p. 637).

n d consolidation of the fracture is slowly completed in succeeding months y which weight bearing may be permitted

Drilling and nailing the fracture—If union of the fracture is less advanced nut there is still minimal shortening of the neck of the femur and no evidence of necrosis of the head nailing of the fracture is indicated exactly as for recent injuries Before the nail is inserted the fractured surfaces may be drilled in many directions in order to break down the sclerosis of bone If the delayed union is associated with adduction deformity this must be corrected by an osteotomy performed when the fracture is drilled and nailed but whenever possible an osteotomy is to be avoided because the main advantage of the nailing technique is freedom from the discomforts and dangers of plaster immobilisation

Grafting or nailing and grafting the fracture—A piece of the shaft of the fibula may be driven across the fragments *instead of a three-flanged nail* [1–] This is permissible only when there is some degree of union of the fracture because a fibular graft alone is not strong enough to be relied upon King [3] has shown that there is ample space within the neck of the femur for both a graft and a nail Two guide wires are introduced one into the upper and one into the lower part of the neck A three flanged nail is driven over the lower wire and the other is used to guide cannulated drills which prepare a track for the fibular graft, the surface of which is freshened and drilled before it is introduced (Fig 1123) This combined operation is especially valuable in old patients of sixty to eighty years of age for whom recumbent treatment in plaster may be dangerous It should not be attempted however if there has been evidence that the blood supply of the femoral head is impaired

If in any femoral neck fracture an indication arises for removal of the nail before final and undoubted consolidation has been secured a useful precaution is to replace the nail by a fibular graft In the case shown in Figure 1122 the fracture had been drilled and nailed eight months after injury The lower half of the line of fracture united soundly but in the upper half where there had been absorption of bone complete consolidation was not secured until the nail had been replaced by a fibular graft

Reconstruction operations—If most of the neck of the femur has disappeared grafting or nailing the fracture is inadvisable Three types of reconstruction operation were performed in earlier years (Fig 1148) Whitman s operation [4-6] consisted of removal of the head of the femur downward displacement of the greater trochanter to a lower level of the shaft and implantation of the stump of the neck of the femur in the acetabulum Immobilisation in plaster was necessary for about six weeks and the results were fairly satisfactory [8] In Colonna s operation [8] the femoral head was removed and the gluteal muscles were dissected off the greater trochanter, which was implanted in the acetabulum The muscles were stitched to a

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Henderson, M S "Un-united Fractures of Neck of Femur treated with Bone Graft." *J Bone Joint Surg.*, 1940, 22, 97
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Phemister, D B. "Aseptic Necrosis of Bone." *J Bone Joint Surg.*, 1930, 12, 769
Hallock, H Arthroplasties and Reconstructions of Hip Joint (Seventy Cases). *Surg Gyn Obstet* 1939 68, 104.
Colonna, P C "New Reconstruction Operation of Neck of Femur" *J Bone Joint Surg.*, 193- 17 110.

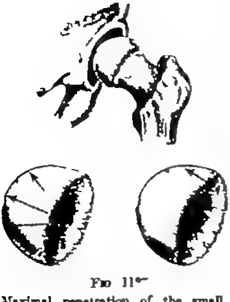


FIG 1127

Maximal penetration of the small proximal fragment of the femoral head can be secured only if the nail enters it almost in the middle of the fractured surface.

to thread over it a cannulated nail which can be hammered home with safety (Fig 1128) Some surgeons have used a thin Kirschner wire as a preliminary directing device but there are several reasons why this is unwise The whip of a thin wire makes it much more difficult to place accurately than a more firm and resistant wire of heavier gauge Moreover it is a mistake to drive in the wire with a power driven tool, which is the only way in which a Kirschner wire can be introduced If heavier wire is introduced by means of a simple T handle with the sense of touch it is perfectly easy for the surgeon to feel his way through the cancellous bone of the femoral neck and to know when he is going wrong he can tell by the feel of it when he passes the fractured surfaces and by the slightly greater resistance at the subchondral level, to know when he is reaching the articular level Thus also resolves every difficulty that there might otherwise be in calculating the required length of nail It becomes an easy matter

Calculation of length of nail—It is clearly useless to measure the length of the femoral neck in ordinary x ray films because unless special precautions have been taken the shadow of the bone on the film is magnified to a degree that varies widely according to the distance of the tube from the limb Many devices have been suggested by which to allow for this magnification (and in earlier years I devised some myself) But they are quite unneeded the guide wire gives the simplest of all answers It is driven into the bone and when inserted in what is believed to be the best axis and correct penetration x ray films are taken If radiographs show accurate penetration to a level just beneath the articular surface the surgeon has only to measure the projecting length of wire and subtract it from the known total length to know precisely the length of nail he needs

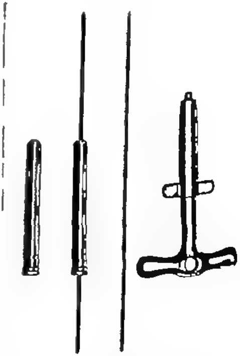


FIG 1128

Cannulated three-flanged nails, heavy guide wires eight inches long and T handle for inserting the wires by sense of touch.

Directing apparatus for the guide wire—Much ingenuity has been shown in devising apparatus by which to

The sources of failure of attempted bifurcation osteotomy were described clearly by McMurray[1] The level of osteotomy must be immediately below the lower margin of the head of the femur so that the shaft can be placed beneath the head The osteotomy must be slightly oblique in an inward and upward direction and the outer angle of the shaft should be broken up

Fig 1150

Fig 1151

Un-united fracture neck of femur before and after bifurcation osteotomy It is obvious from the first radiograph that the femoral head is relatively dense and therefore avascular No type of nailing or grafting operation is justifiable.

and freshened in order that it shall certainly unite with the trochanteric fragment The limb should be immobilised in plaster in slight abduction with the femur in its inwardly displaced position until the osteotomy is united (Figs 1150 1151)

Replacement of the femoral head by plastic or metal prosthesis—In old or un united fractures it is sometimes best to remove the femoral head and replace it with a plastic or metal prosthesis This method of reconstructive surgery of the hip for old fractures is still under trial

[1] McMurray T P Un-united Fractures of the Neck of the Femur *J Bone Joint Surg* 1936, 18, 319.

CHAPTER XXV

INJURIES OF THE THIGH

If it should be discovered that I have added one atom to the principle it will give me much more satisfaction than if I should succeed in burdening practice by ingenious means —HUGH OWEN THOMAS 1886

Liverpool is proud of her heritage of medical and surgical pioneers of whom one of the greatest was Hugh Owen Thomas father of British orthopedic surgery and founder of the Liverpool school who once expressed the hope that he would not be remembered as an inventor of splints The lathe room at 11 Nelson Street where he designed and made his own appliances is of course world famous (Fig 1152) but his important contribution to medicine

FIG 1152

The lathe room of Hugh Owen Thomas at 11 Nelson Street, Liverpool.

and surgery was the declaration of certain principles which will survive long after his splints may have been forgotten [1 2] His father Evan Thomas descendant of many generations of unqualified bone-setters who had practised in the hills of Wales having suffered the bitter antagonisms of qualified contemporaries determined to send all five of his sons to study in Edinburgh for the medical diploma which would protect their practice of the hereditary craft The eldest Hugh Owen Thomas was a delicate child and a spare frail man—but he worked in Liverpool for fourteen hours a day seven days a week for thirty five years without a holiday With irrepressible energy and fortitude this eccentric man darted along the

Frederick Watson. "Hugh Owen Thomas—a Personal Study" London Oxford University Press, 1934
H O Thomas "Diseases of the Hip, Knee and Ankle Joints." Liverpool T Dobb & Co., 1875.
H O Thomas. "Contributions to Surgery and Medicine—Part VII. Fractures, Dislocations, Deformities and Diseases of the Lower Extremities." London H. K. Lewis, 1890.

Fig 1170

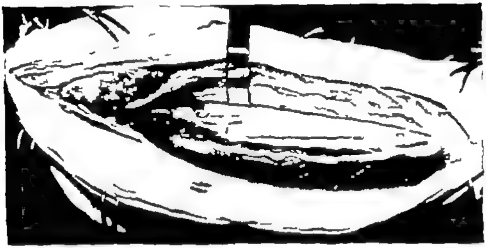


Fig 1171

Fig. 1172

Henry's muscle-splitting exposure of the femur

These photographs show exposure of the right femur the hip joint is to the left and the knee joint to the right. The incision is along the line from the anterior superior spine to the patella. The interval between rectus femoris and vastus externus is defined (Fig 1170) The silvery crureus is exposed (Fig 1171) with the circumflex vessels and nerve to the vastus externus crossing it obliquely downwards and outwards. The vessels and nerve are retracted and the muscle is split in the line of its fibres down to bone (Fig. 1172)

corridors of 11 Nelson Street inspiring and cajoling a multitude of patients, despising the professional manner scorning anaesthetics whipping a wrench from beneath his tail coat refracturing and resetting a mal united fracture before the victim had time to think. Power prestige and reward were as nothing to him but he won such a place in the hearts of seamen dockers and housewives that when he died in harness they lined the streets of Liverpool in their thousands sobbing testimony to the friend they had lost. His was a sleepless search for truth He fought aggressively and fearlessly

That the teaching of Hugh Owen Thomas endured is the great triumph of his nephew Robert Jones In the words of John Ridlon The greatest thing that Robert Jones ever did was to make the main principles of Thomas acceptable to the profession

The principles taught by Hugh Owen Thomas are certainly not forgotten. The Thomas knee splint is still an essential feature of the routine management of many fractures of the shaft of the femur which compares favourably with every other method of treatment Most fractures of the femoral shaft can be dealt with successfully by this conservative technique of immobilisation At the same time it should be recognised that in some fractures, particularly in the middle and upper thirds of the shaft of the femur the internal fixation of a long intramedullary nail offers notable advantages

The femur is richly supplied with blood and the repair of fractures of this bone is usually so rapid that it is even difficult to stop them from uniting Non union is almost unknown provided only that there has been no serious infection and no mismanagement by the use of excessive traction On the other hand it should be recognised that final consolidation is sometimes slow and that the distribution of muscle forces is such that angulation may arise The powerful abductor muscles are all inserted in the region of the greater trochanter whereas the equally powerful adductor muscles are inserted into the medial aspect of the lower femoral shaft and the medial femoral condyle so that there is always a tendency for the proximal fragment to be abducted and for the distal fragment to be adducted Such lateral angulation may develop even in later stages of treatment after a fracture of the femoral shaft has been suitably immobilised for twelve or fifteen weeks and it is in fractures which are slow in uniting that the continued protection of an intramedullary nail finds its greatest benefit

Thus in considering the management of fractures of the shaft of the femur we must review 1) conservative treatment by skin traction or skeletal traction in a Thomas splint 2) operative treatment by the internal fixation of a long intramedullary nail

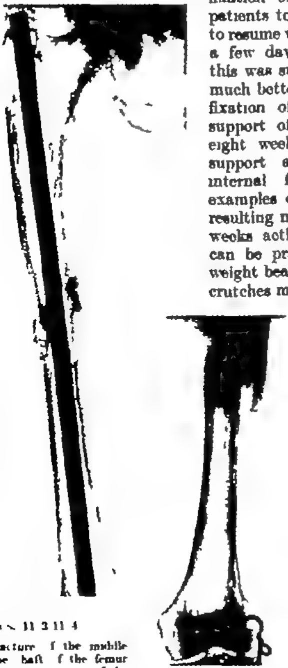
TREATMENT OF FRACTURES OF THE SHAFT OF THE FEMUR IN A THOMAS' SPLINT

Most fractures of the femoral shaft can be treated satisfactorily in a Thomas knee splint with skin traction or skeletal traction It must be emphasised at once that as with every other fracture displacement should first be reduced by manipulation the splint being expected only to hold the reduction that has been achieved Many failures in the treatment of fractures of the femoral shaft have arisen from endeavours to secure gradual

At the same time it is always wise to have a sterilised hacksaw on the table so that if by chance the nail does become locked it can be cut off. Very recently it was suggested that there was particular difficulty in cutting the end of a stainless steel or vitallium stem of a hip prosthesis or of a nail used for the internal fixation of a fractured femur. Indeed it was said that someone took three hours in a fruitless endeavour to do so and a special diamond rotatory cutter was proposed.[1] All I can say is that they ought to go to my ironmonger from whom last week I bought a hacksaw for two shillings which cut off such a projecting nail in five minutes!

After-treatment—Many surgeons have relied entirely on the intramedullary fixation of a nail and have allowed patients to move freely in bed or even to resume weight bearing activity within a few days of operation. Sometimes this was succeeded but in general it is much better to supplement the internal fixation of a nail with the external support of a plaster spica for about eight weeks. Without such external support and with entire reliance on internal fixation there have been examples of loosening of the nail and resulting non union. After about eight weeks active exercises at the knee joint can be practised. Shortly after that weight bearing with the support of crutches may begin.

There is no need for a caliper splint; indeed it is better not to use one. The nail seldom needs to be removed until after many months or even years, and its protection from late angulation is of course invaluable. Occasionally there may be discomfort in the trochanteric region at the site of the head of the nail when the patient lies in bed on one side but this is seldom important. In one interesting case a distinguished scientist complained of discomfort in the region of his nailed femur whenever



FIGS. 313, 314

Oblique fracture of the middle third of the shaft of the femur treated by open exposure of the fracture and intramedullary nailing through the greater trochanter

[1] Kessler, H. H., and [illegible], H. M., J. Bone Joint Surg., 1951, 33-A, [illegible]

reduction by long-continued traction without ever giving an anaesthetic or deliberately manipulating the fragments into apposition. Surgeons who in the treatment of other fractures would never have doubted the need for manipulative correction of displacement with maintenance of correction thereafter by suitable splintage have expected miracles from a Thomas splint which they supposed would reduce the fracture as well as immobilise it. The displacement should be reduced by manipulation within a few hours of injury. No more is to be expected of the splint, whether used with skin traction or skeletal traction, than to maintain the replacement so achieved. Reduction of the fracture should be completed before the surgeon leaves the bedside, with the fractured surfaces in reasonable apposition and

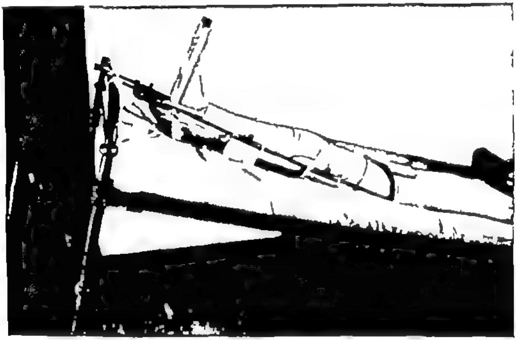


FIG. 1153

Fixed traction from adhesive skin tapes in a Thomas splint. The end of the splint is fastened to the raised foot of the bed to reduce the pressure of the ring of the splint on the ischium. This is the simplest of all methods of treating fractures of the shaft of the femur and it is safe and satisfactory. For clarity of illustration the local splints bandaged to the thigh by which to maintain alignment are not shown.

with alignment controlled by local gutter splints or plaster slabs as well as by the main support of the Thomas splint with light traction.

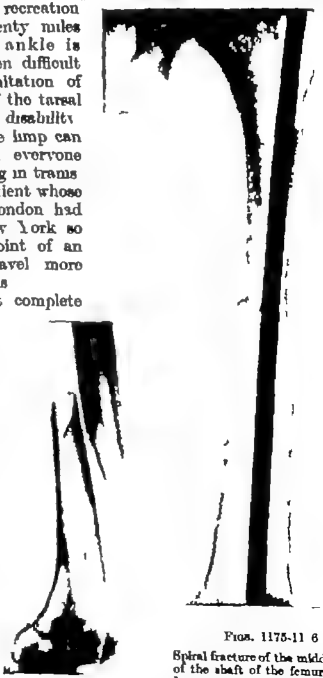
Technique of immobilisation of the limb by traction in a Thomas' splint. There are many methods of supporting a fractured thigh in a Thomas splint but they *differ only in detail.* *It must first be said quite clearly* and definitely that after manipulative reduction the simplest and safest of all methods is fixed traction with adhesive skin tapes tied to the lower end of a Thomas splint as illustrated in Figures 1153-1155. If this simple technique is used with proper attention to detail nearly all fractures of the shaft of the femur can be treated successfully—without serious shortening, without deformity, without stiffness of the knee joint and of course without any threat of non union. It is an admirable method of treatment which for long years has stood the test of time. Displacement must of course first be reduced

he took a glass of sherry, or any other form of alcohol which disappeared immediately when the nail was removed. This symptom, recorded by a shrewd observer, is of interest in relation to the deep pain that is known to be caused by alcohol in patients with lymphadenomatous glands—but this seems to be exceptional and in the ordinary way it is quite safe to leave an intramedullary nail in position indefinitely or at least for several years.

STIFFNESS OF THE KNEE JOINT IN FRACTURES OF THE SHAFT OF THE FEMUR

The penalty of stiffness applies more severely to the knee than to any other joint of the lower limb. If a hip is ankylosed in good position the patient can engage in every recreation and even walk ten or twenty miles without a limp. If an ankle is arthrodesed firmly it is often difficult to know that there is limitation of movement. Sound fusion of the tarsal joints causes little or no disability. But when a knee is stiff the limp can scarcely be concealed, and everyone falls over the outstretched leg in trams, trains and theatres. One patient whose knee was arthrodesed in London had his limb amputated in New York so that he might bend the joint of an artificial leg and thus travel more comfortably in crowded trains.

There is no doubt that complete stiffness of the knee is a serious disability and that fibrous ankylosis which permits a few degrees of movement is even more serious because every strain causes painful reaction. It is wise that in the treatment of fractures of the shaft of the femur surgeons should direct their attention to preventing stiffness of the knee—but at the same time it is foolish to suggest that these fractures differ from all others in that vigorous movement must be practised from the beginning. The proposals of Fisk and of Roger Anderson to which



FIGS. 1175-11 6

Spiral fracture of the middle third of the shaft of the femur treated by operative exposure of the fracture with intramedullary nailing from the trochanter

by manipulation the corrected position then being maintained for about twelve weeks by skin traction in a Thomas splint with suitable local splinting There need be no fear of permanent stiffness of the knee joint. Such stiffness does not arise just from immobilisation in a splint The causes of stiffness of the knee in fractures of the shaft of the femur will be discussed later but meanwhile let it be clear that in young and middle aged patients fixation of the knee joint for three or four months in the treatment of a fracture of the femoral shaft does no harm at all Nearly all such fractures can be treated successfully by fixed traction from skin-tapes in a Thomas splint (Figs. 1154-1155)

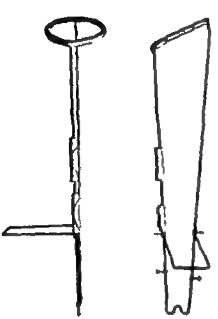


Fig. 1154

Thomas bed knee splint with leather slings and foot supporting frame attached

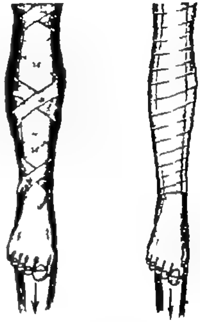


Fig 1155

If spiral adhesive strapping is applied pressure sores are produced.

Thomas splint—A Thomas splint consists of a ring of $\frac{3}{8}$ inch iron, covered with boiler felt and basil leather, set at such an angle to two side bars that it fits round the upper thigh with the posterior more curved part of the ring under the tuberosity of the ischium and the flatter part just below and parallel to the inguinal ligament (Fig 1154) The outer bar is joined to the middle of the ring the middle bar slightly in front of the middle and they converge at the lower ends where they are continuous at a level three or four inches below the foot a notch in the crossbar serving for the attachment of extension cords The limb rests upon strips of canvas or calico which are slung between the side bars of the splint

Pearson s knee flexion attachment—It has been affirmed that in most patients with a fracture of the shaft of the femur fixation of the knee joint for about twelve weeks does no harm but there are occasions when it is wise to begin movement of this joint before union of the fracture is sound enough for the splint to be discarded Such movement is facilitated by the use of a Pearson s knee-flexion attachment—a U-shaped metal frame hinged

reference has already been made by which the knee joint is exercised vigorously through a wide range of movement even within the first few days after injury, are panic measures The fact is that it is no more harmful to immobilise a knee for three or four months in treating fractures of the shaft of the femur than to immobilise an ankle in fractures of the tibia, a wrist in fractures of the radius an elbow in fractures of the humerus or indeed to immobilise any joint in the treatment of any fracture

The first essential is to secure rapid union of the fracture Any attempt to move and exercise joints which interferes with immobility of the fractured bone defeats its own object The aim of treatment must be to secure prompt union of the fracture because it is only when union is slow or delayed that serious problems of stiffness arise *In nearly all fractures of the femur the sure method of preventing permanent stiffness of the knee is to maintain uninterrupted immobilisation until there is at least early union of the fracture and then to regain movement by active exercise without forcible stretching or manipulation*

Three types of stiffness of the knee after fracture of the shaft of the femur—We have considered stiffness from the immobilisation of uncomplicated fractures, but there are three different causes of stiffness of the knee in fractures of the femur 1) stiffness from adhesion formation in and around the joint 2) stiffness from fixation of the patella to the femoral condyles 3) stiffness from anchorage of the quadriceps muscle to the femur at the site of fracture

Stiffness from simple adhesion formation around the knee—This has already been recognised as an inevitable consequence of the necessary immobilisation of fractures of the femoral shaft but there need be no concern because a full range of movement will nearly always be regained by active exercise provided only that passive stretching repeated manipulation and other such forcible methods are avoided The tendency to stiffness will have been minimised 1) by ensuring that throughout the period of immobilisation the joint is in a slightly flexed position, short of full extension and never in hyperextension 2) by maintaining functional activity with active exercise of the toes, foot and ankle and repeated static contraction of the quadriceps muscles 3) by arranging that a physiotherapist prevents fixation of the patella to the femoral condyles with gentle passive lateral movements from one side to the other 4) in the occasional case of slow or delayed union by encouraging gentle flexion movements of the knee after about the third month without interfering with fixation of the fractured fragments, either with the aid of a Fisk or Pearson attachment to the Thomas splint or perhaps with the internal fixation of an intramedullary nail Whether the fracture has been treated by fixed traction balanced traction intramedullary nail fixation or immobilisation in a plaster spica the time comes after three or four months when there is clinical union of the fracture but not yet sound consolidation More vigorous exercises should then be encouraged while the patient lies in bed or with the limb hanging over the side of the bed It is better not to use a caliper splint which restricts mobilisation of the knee If union is sound enough such a splint is unnecessary and if union is not sound the splint is harmful in that it prevents regular flexion movements It is better to use two crutches thus avoiding the risk of refracture from premature weight bearing but at the same time permitting

at its upper end to short clamps fitting over the side bars of the Thomas splint just above the level of the knee The thigh having been supported in the main part of the splint by broad strips of canvas stretched between its bars the leg and foot are supported in a Pearson knee flexion attachment on similar canvas strips The Pearson attachment may be fixed at any desired angle with the main splint or with a movable junction, it may become part of a balanced system of weights and pulleys so that active flexion exercises of the joint can be practised by the patient

Slinging the splint and special fracture beds—Whether skin traction or skeletal traction is used suspension of the splint from an overhead beam increases the comfort of the patient, allows him to move more freely in bed, and facilitates the nursing problems Many types of fracture bed are available, the essential feature of them all being a rigid overhead beam supported by two uprights, one clamped to the foot of the bed and the other to the head of it Provision is made for the attachment of pulleys at any desired point on the beam or on the uprights

Application of traction—Two methods of traction are available 1) skin traction by adhesive strapping ; 2) skeletal traction from a Steinman pin or Kirschner wire in the upper part of the tibia or lower end of the femur Each has its advantages and limitations—sometimes one is better and sometimes the other Surgeons should be ready to use either skin traction or skeletal traction according to the needs of the case

Skin-traction with adhesive strapping—When no more than light traction of about ten pounds is required adhesive strapping affords a sufficient hold and is entirely satisfactory if the skin is healthy When the skin is atrophic and inelastic as it may be in elderly patients even light traction may cause discomfort or give rise to ulceration of the skin and in these patients skeletal traction from a tibial pin is better—but adhesive strapping is usually good enough so long as it is used properly Three-inch wide adhesive traction tapes are applied one on each side of the limb from just above the ankle to the mid thigh The outer strip should be centred slightly behind the mid line of the limb the inner strip slightly in front, so that when the tapes are fixed to the cross bar at the lower end of the splint the tendency for the limb to roll into external rotation is controlled The traction-strapping must not be bound to the limb by spiral turns of adhesive strapping because this always causes pressure sores (Fig 1155) Day after day as the strapping is pulled it must tend to slide down the limb and over a period of six or eight weeks it may slide as much as two inches If other strips of adhesive are applied transversely or spirally round the limb they must also be pulled down the sharp lower edge of each strip thus cutting into the front of the ankle over the tendo-Achillis on the crest of the tibia or in the region of the knee joint The longitudinal strips of traction strapping should be bound in position only with soft encircling bandage which does not adhere to it After some weeks it may sometimes be necessary to replace the adhesive strapping and apply new traction tapes but there should really be *no* difficulty in avoiding pressure sores

Skeletal-traction—When the skin is injured or ulcerated when it is atrophic and inelastic or on the few occasions that a very heavy pull is needed skeletal traction should be used A Steinman pin is driven through the tibia in the region of the tubercle with a U shaped stirrup from which a cord is

repeated flexion exercise of the joint At this stage of treatment it is the duty of the surgeon to encourage the patient—to stimulate urge cajole and inspire—but not to force Very few knee joints stiff from simple adhesion formation need be manipulated under an anæsthetic

Stiffness of the knee joint from fixation of the patella—Fixation of the patella to the front of the femoral condyles is an important cause of stiffness In young and healthy patients this should usually be prevented by a physiotherapist who not only supervises static quadriceps contraction but also maintains lateral movement of the patella by gentle passive movement repeated every day Sometimes however when the shaft of the femur is fractured there is also injury to the knee with traumatic synovitis damage to the articular surfaces or even a stellate fracture of the patella If the patella is thus fixed to the femur forcible manipulation of the joint under an anæsthetic is still more disastrous—the quadriceps tendon or the patellar ligament will be avulsed or the bone itself may be fractured It is important to recognise patello-femoral ankylosis before attempting mobilisation of a stiff knee by forcible manipulation It is often best to spend many months with the daily care of a physiotherapist who mobilises the joint by gentle passive manipulation If after trial of such conservative measures there is still serious stiffness the patella may need to be excised It is removed by subperiosteal dissection and after the joint has been manipulated to a right angle the quadriceps tendon is repaired. Active flexion exercises are encouraged within two or three weeks of the operation

FIG 1177

Fracture of the patella from forcible manipulation under anæsthesia of a knee joint stiff from anchorage of the quadriceps muscle to the femur

Fixation of the quadriceps muscle to the shaft of the femur near the site of fracture—At the moment that a fracture of the femur is sustained the fragments of the shaft of the bone may tear into the deep surface of the quadriceps and cause fixation of muscle to bone When there is an open or compound fracture perhaps with infection the muscle becomes still more firmly anchored This is probably the most serious of all causes of stiffness of the knee joint in fractures of the shaft of the femur especially if endeavours are made to gain mobility by forcible manipulation under anæsthesia which must almost inevitably fracture the patella or avulse the patellar ligaments (Fig 1177) Every effort should first be made to restore movement by active exercise continued hour by hour and day by day over many months If such measures fail and there is still serious incapacity from stiffness it may be wise to lengthen the quadriceps tendon below the site of anchorage of the muscle Through an anterior midline incision the vastus medialis and lateralis are separated from the crureus tendon and after the joint has been flexed to a right angle they are sutured with V Y lengthening (the first division of the muscle insertions being in

Methods of traction—A distinction should be made between fixed traction and balanced traction In fixed traction the adhesive straps are attached firmly to the end of the Thomas splint with as much tension as is needed. They are tightened once or twice a day The counter thrust of the splint in the region of the ischium can be reduced by fixing the lower end of the splint of the foot of the bed which is raised (Fig 1153) In balanced traction the cord attached to the stirrup and skeletal pin is passed directly over a pulley at the foot of the bed to a weight of about ten pounds suspended from it The choice between fixed and balanced traction is largely a matter of preference (Figs 1156-1157) Satisfactory results can be achieved by

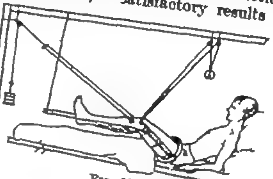


FIG 1158
Fisk traction for fractures of the shaft of the femur

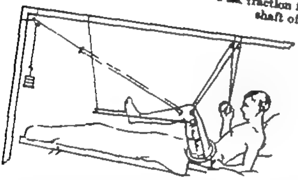


FIG 1159

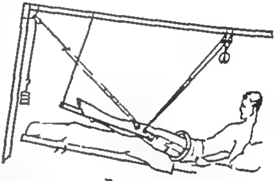


FIG 1160

In this method a Thomas splint is used with a Pearson's flexed knee attachment and skeletal traction from a tibial pin. The lower part of the bars of the Thomas splint, being no longer needed, are sawn off The idea of Fisk was that in this way the knee joint could be mobilised from the beginning For myself I still have considerable doubt as to whether it was a good idea. I still believe that when the shaft of the femur is fractured the limb should be rested for a few weeks—and this means that the knee joint should be rested. That is what I would want for my own fractured thigh.

each of these methods The technique of balanced traction does allow the patient to raise himself in bed and to move with freedom without disturbing the position of the fractured bone and moreover it offers the advantage of allowing earlier mobilisation of the knee joint The arrangements of cords, pulleys and weights shown in Figures 1156-1157 are commonly used but there are alternatives which are satisfactory

Other methods of suspension traction—The methods of fixed or balanced traction from skin tapes or skeletal pins already described are adequate for most fractures of the femoral shaft but other systems of traction may sometimes be preferred (Figs 11,8 1163)

Fisk traction—This method of treatment of fractures of the femoral shaft does not differ basically from the technique of skeletal tibial traction in

the form of a Λ and the suture in the form of a λ) The joint is supported in 30 degrees of flexion for two or three weeks and active exercises are then begun Such lengthening of the quadriceps tendon restores flexion movement only at the cost of loss of active extension and at first there is an extensor lag—the knee can be extended by passive movement but it cannot be extended fully by active movement The disability of an extensor lag with loss of active control of the last 30 or 40 degrees of extension movement of the knee may be considerable especially when the patient moves in a crowd, perhaps being thrown to the ground from a simple thrust behind the joint which cannot be controlled by muscle contraction At the same time it is encouraging to note how often this lag is picked up in the course of years if the patient is energetic in his exercise Some patients especially those who are enthusiastic in after treatment have picked up as much as 40 or 50 degrees extensor lag after lengthening of the quadriceps tendon when the muscle had been adherent to a comminuted fracture of the shaft of the femur

SUBTROCHANTERIC FRACTURES OF THE FEMUR

Fractures of the upper shaft of the femur near the level of the trochanter show typical displacement The strong gluteal muscles which are the abductors of the hip are attached to the proximal fragment in the region of the greater trochanter whereas the adductor muscles are inserted below the level of the fracture so that the proximal fragment is abducted even as much as 45 degrees The first principle of treatment of these fractures is to immobilise the limb in a similar position of at least 45 degrees of abduction The fracture may be oblique from above downwards and medially but sometimes the obliquity is in the opposite direction from above downwards and laterally (Fig 1178) The first type of fracture is stable when the limb is abducted and it is enough to immobilise the limb in a plaster spica The second type is not stable unless there is continuous traction because the shaft of the femur tends to be pulled inwards and there is therefore a danger of non union (Fig 1180)

Treatment in a Thomas splint—No matter what the plane of obliquity may be these subtrochanteric fractures can often be treated successfully in a Thomas splint with skin or skeletal traction the splint being slung with the limb in abduction and flexion so that the pull of the gluteal and ilio-psoas muscles is neutralised It is fortunate that the fracture lies so close to a ball and socket joint that perfect accuracy of alignment is not essential and minor degrees of angulation cause little or no functional disability

Immobilisation in a plaster spica—Subtrochanteric fractures of the stable type oblique from above downwards and medially can be treated quite safely in a plaster spica with the lower limb in 45 degrees of abduction and some flexion It is wise to use a double spica including both hip joints in order to control movements of the pelvis It must be emphasised however that this treatment should not be used for fractures oblique in the opposite direction because the upper end of the shaft of femur may then displace under the capsule of the hip joint and the surfaces of the fragment are often sealed by overlying muscles so that there may be failure of union

a balanced Thomas splint with Pearson's flexed knee attachment as illustrated in Figure 1157 but Fisk has simplified the splinting and made it possible for there to be a still greater range of knee movement at an even earlier stage of treatment He rightly decided that if there was to be a Pearson flexed knee attachment to a Thomas splint the lower half of the bars of the Thomas splint no longer served any useful purpose—and so he cut them off From the sawn ends just above the level of the knee he attached suspension cords passing over a pulley to a four pound weight near the head of the bed which the patient could seize and pull thus aiding his own active flexion exercises of the hip and knee joints even to the right angle,

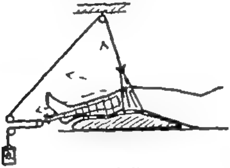


Fig 1161

Russell traction. This technique has often succeeded, but it is not recommended for fractures of the femur

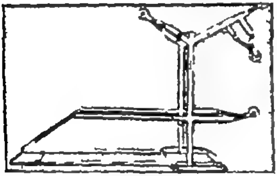


Fig 1162

Bohler Braun splint with four pulleys for fractures of the shaft of the femur

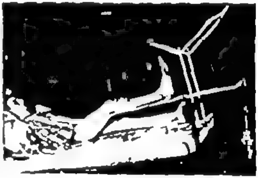


Fig 1163

Braun splint with tibial traction. This is not recommended for fractures of the femur

while still depending on the continuous traction of about ten pounds from a skeletal pin in the upper end of the tibia (Figs 1158-1160) Whether Fisk is right in encouraging such vigorous movement over so wide a range at so early a stage of treatment is very much open to doubt In most young and adult patients it does not matter in the least that the knee joint is immobilised for three or four months a full range of movement will always be regained But there are more elderly patients whose arthritic knee joints have been injured at the time that the femur was fractured and in whom earlier movement may be advisable At least we would prefer this compromise of firm fixation of the limb in a sawn-off Thomas splint with Pearson attachment and early active mobilisation of the knee with all the

Fig 1178

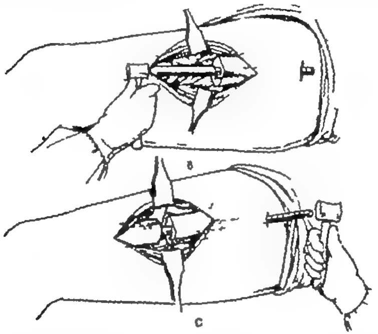
Fig 1179

Subtrochanteric fracture of femur before reduction and after immobilisation in abduction with continuous traction. The obliquity of the fracture is such that a plaster spica alone would be unsafe Continuous traction is needed.

Fig 1180

Unstable type of subtrochanteric fracture of the femur treated without sufficient traction and fixation, so that there was non union from inadequate apposition and muscle interposition There should have been traction in a Thomas splint or abduction frame or alternatively internal fixation with an intramedullary nail.

was driven from the trochanter through the medulla of the proximal fragment into the distal fragment, and then a nail was threaded over it. This has caused many complications. In the first place so much x-ray exposure was needed during the operation that there was danger to the surgeon and his assistants of damage to the skin of their faces and hands; and in the second place there was danger to the patient because nails were sometimes driven through the cortex of the bone with damage to the femoral artery. Many disasters have been reported from the technique of blind intramedullary nailing of the femur and other long bones.



Figs. 1100-1102

Hey Groves' method of intramedullary nailing of fractures of the shaft of the femur, the nail being introduced in a retrograde manner through the trochanter and then being hammered back into the distal fragment. (From Hey Groves' "Modern Methods of Treating Fractures," 1921, by courtesy of the publishers, John Wright & Sons Ltd., Bristol.)

Most surgeons in Britain, America and elsewhere have now reverted to the technique of open exposure of the fracture so that the fragments can be seen as they are replaced with accuracy, and the nail can be seen as it passes from the proximal to the distal fragment, without the obscurity of x-ray screening which is often misleading.

Even when the fractured fragments are exposed and intramedullary nailing is performed under direct visual control there are still possibilities of serious trouble. It is obvious that if too slender a nail is introduced the fixation will be imperfect, but it is still worse to drive in a nail that is too wide for the medulla of the femur—it may even be disastrous. When this has been attempted the femur has sometimes been shattered. Still more often, when too wide a nail was hammered in it became so tight that it could neither be driven further nor be extracted. There is one record of surgical heroism throughout a four hour operation in which a nail had been driven through the site of fracture of a femur into the proximal fragment and, having been seized, was with very great difficulty removed after which

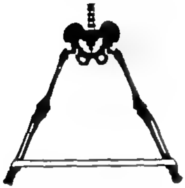


Fig 1185

Abduction of one hip can be maintained by fully abducting the other hip and joining the feet with a rigid crossbar

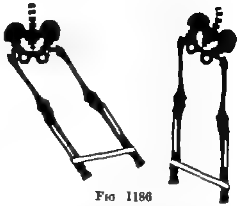


Fig 1186

Similarly abduction of one hip is maintained if the other hip is fully adducted and the feet are joined by a crossbar

Fig. 1187

Well leg traction for subtrochanteric fractures by the technique illustrated in the diagrams above

Fig 1168

Fig 1169

Intramedullary nail fixation of a fracture of the shaft of the femur

Spiral fracture of the upper shaft of the femur with separation of the lesser trochanter showing the usual tendency to outward angulation, the proximal fragment being abducted by the gluteal muscles and the distal fragment adducted by the powerful adductor muscles of the thigh (Fig 1168). The fracture was exposed by Henry's approach and an intramedullary nail was inserted from the greater trochanter under direct visual control by the technique described.

Fig 1188

Subtrochanteric fracture of the femur in the patient shown in Figure 1187

Fig 1189

The fracture is reduced as soon as the splint is applied (radiograph with portable apparatus).

Fig 1190

Despite the obliquity of the fracture line which makes reduction unstable, over riding has been prevented by the traction of the well leg splint Full abduction has been maintained and the fracture is firmly united although the

a guide-wire driven up from the site of the fracture to the trochanter togeth with a nail driven over it from the trochanter into the femur were be inextricably fixed—the surgeon then being faced with the horrible situati of six inches of guide wire protruding from the wound of the thigh a eight inches of nail protruding through the incision over the hip neit being capable of removal These complications were discussed in a rece issue of the *Journal of Bone and Joint Surgery* when the history medullary nailing of fractured bones was reviewed [1] There can be no dou about the merit of this operative procedure but at the same time there c be no doubt that unless the technique is followed with attention to ev detail there are many sources of grave complication

Technique of operation—The fracture should be exposed through anterior mid line Henry incision (Figs 1170 1172) The first step is to cle the bone surfaces and if the fracture is more than a few weeks old, to remo the young callus and open the medulla of the fragments. A series long handled 12 to 18 mm drills or burrs is then passed, first proxima and then distally, by which to determine the exact internal diameter of t medulla of the bone A 12 mm drill is introduced into the proxim fragment If it passes easily a 14 mm drill is introduced. If even t is too small the next-sized drill is passed When the correct diameter the drill or burr has been determined the corresponding diameter of n is known and all that is needed is to estimate the exact length From the site of fracture a guide wire is passed down the medulla of the distal fragment and resistance is felt when it approaches the articular surface of the knee by measurement of the length of wire still outside the bone the exact length from the site of fracture is known The guide wire is then passed up the medulla of the proximal fragment until resistance is felt against the trochanter so that once again there can be an exact measurement of the length. Thus is known the required length of nail—but we must add that the length finally chosen should be about one inch less than the measurements shown by the explorations of the guide wire because it is far better that the point of the nail should lie about one inch short of the femoral articular surface than that it should be so long as to penetrate the joint surface

The guide-wire driven from the fractured surface into the proxima fragment is then pushed still further and a short incision is made over the point of its emergence from the trochanter A flanged nail already known to be correct in both width and length, is driven from the trochanter over the guide wire until the point is seen to appear at the site of fracture The guide wire is removed The fragments are then held in correct appositio and alignment while the nail is driven into the distal fragment Great car must be taken to see that alignment is maintained with complete accurac throughout this last step because otherwise the point of the nail can easil be driven through the cortex of the distal fragment especially when the bon is porotic

With the precaution of using a preliminary drill or burr by which to determine the width of the medullary canal there should no longer be disasters from the seizing of nails in a narrow femoral medullary canal

[1] Watson-Jones, R., Adams, J. C., Bonnin, J. G., Burrows, H. J., King, T., Nicoll, E. A., Palmer, I., Vom Saal, F., Smith, H., Trevor, D., Vaughan-Jackson, O. J., Le Vay, A. D. "Medullary Nailing of Fractures after 15 Years with Review of the Difficulties and Complications." *J. Bone Joint Surg.* 1950, 32-B, 694.

SUPRACONDYLAR FRACTURES OF THE FEMUR

Few injuries present more difficult problems than supracondylar fractures of the femur. The trouble is that this injury is so rare that few surgeons have sufficient experience of it. There can scarcely be a surgeon in the world who has treated more than ten or twenty such fractures with serious displacement. The small distal fragment has only one muscle attached to it, namely the gastrocnemius, which tends to pull it into a flexed position (Fig. 1101). If this tilting is not corrected and the fracture unites with backward angulation a serious disability arises from genu recurvatum. Another and even more urgent hazard may arise from the vulnerable position of the popliteal artery, which is sometimes damaged at the time of the injury or may at a later stage be compressed by the sharp margin of the lower fragment of the femur.

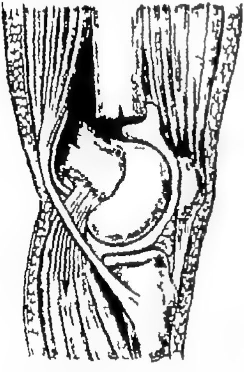


Fig. 1101

The distal fragment of a supracondylar fracture of the femur is flexed by the gastrocnemius muscle.

Efficient control of the distal fragment in this fracture has exercised the ingenuity of generations of surgeons. Although it may be possible to improve the position by manual manipulation and traction there is always difficulty in maintaining the reduction. It was originally taught that if the fracture was immobilised with traction in a Thomas splint the muscle spasm would subside and tilting of the lower fragment would be corrected—but unfortunately this is not always true. Böhler advocated the use of a Braun's frame with the angle of the splint behind the fracture and not behind the knee joint—but again the results were often disappointing.

There are of course many supracondylar fractures of the femur with only slight tilting of the distal fragment which can be controlled quite adequately after reduction of the fracture if the limb is supported in a Thomas splint in a position of slight flexion with continuous traction. The exact degree of flexion of the knee joint that is needed must be determined from radiographs taken at the time of the manipulative reduction. Tibial skeletal traction from a Steinmann pin in the upper end of the tibia is used and the limb is supported in a Thomas splint with a Pearson flexed knee attachment fixed at the required angle. In these fractures so close to the knee joint there should be no hurry in starting quadriceps exercises, and most certainly there must be no early mobilisation of the knee joint. The joints of the toes, foot and ankle may be exercised but rigid immobilisation of the reduced supracondylar fracture should be maintained for at least six weeks before any endeavour is made to exercise the muscles of the thigh or to move the knee joint, which might so readily redisplace the fragments.

Sometimes displacement of the small distal fragment of the femur by the unopposed pull of the gastrocnemius is so pronounced that the simple technique of tibial skeletal traction in a Thomas splint with flexion attachment or the less satisfactory technique of traction in a Braun s splint does not suffice These are the really difficult fractures of which few surgeons have experience of more than two or three cases In the orthopædic service of the Royal Air Force during the last war we had success in a series of cases by driving a skeletal traction pin through the distal fragment of the femur from which vertical traction was applied at the same time that tibial skeletal traction was maintained reduction being confirmed by radiographs taken in the theatre the pins then being incorporated in plaster (Figs 1102 1103)

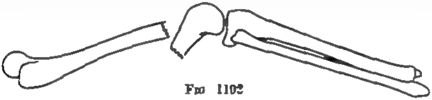


FIG 1102

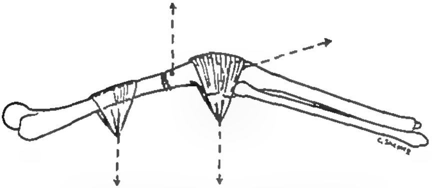


FIG 1103

Technique of reducing supracondylar fractures

Tibial traction is applied with the knee joint slightly flexed. From a pin in the supracondylar fragment, close to the fracture vertical traction is then applied against the counter pull of a canvas sling over the front of the thigh and a second sling over the front of the knee

It is evident that traction pins driven through the femur at this level might easily perforate the femoral artery in Hunter s canal and the technique certainly has its dangers It is probably better in the rare cases of supracondylar fracture of the femur which cannot be controlled by simple tibial skeletal traction in a flexed knee Thomas splint to undertake operative reduction with internal fixation perhaps with an intramedullary nail and when the distal fragment is so short that this is impossible by means of a plate and screws

FRACTURES OF THE CONDYLES OF THE FEMUR

One or both condyles of the femur may be fractured the line of injury of course extending into the knee joint so that there is hæmarthrosis If both condyles are separated by a T or Y fracture it is often possible to reduce the displacement by applying traction with compression of the fragments between the surgeon s hands For example an elderly man sustained a

the middle of the joint in the normal position of the cruciate ligaments [1-6] The anterior cruciate posterior cruciate and medial ligaments may all be reconstructed at the same operation Unfortunately the fascial bands tend to stretch and the final result is seldom better than that which can be achieved by determined and persistent exercise of the thigh muscles

FRACTURE OF THE TIBIAL SPINE

Fracture of the tibial spine is to be regarded as an avulsion of the anterior cruciate ligament together with a fragment of bone from its tibial attachment [7] Almost invariably the fracture occurs between the ages of

FIG. 1211 FIG. 1212

Fracture of tibial spine by avulsion of anterior cruciate ligament The fragment of bone is tilted forwards (Fig 1211). After operative replacement of the fragment, reduction is so stable that internal fixation is unnecessary (Fig 1212)

ten and twenty and it is the injury of adolescents that corresponds in adults to rupture of the anterior cruciate ligament It may be produced by any of the strains causing rupture of the anterior cruciate ligament but it has been shown experimentally and clinically that the most frequent injury is a blow applied to the front of the flexed knee joint which drives the femur

Groves, E. W. Hey "Crucial Ligaments of Knee Joint—Operative Treatment." *Brit. J Surg* 1919 7, 505
Jones, Robert, and Smith, S. Alwyn "On Rupture of the Crucial Ligaments." *Brit J Surg* 1913 1, 70.
Smith, S. Alwyn. "Diagnosis Treatment Injuries of Crucial Ligaments." *Brit. J Surg* 1918, 6, 176.
Edwards, A H "Repair Crucial Ligament (gracilis and semitendinosus)." *Brit J Surg* 1926 13, 432.
Gallie W E and Le Mesurier A B "Repair of Posterior Crucial Ligament." *Ann. Surg* 1927 85, 592.
Macey H B "Operative Repair Crucial Ligaments." *Surg Gyn Obstet* 1939 69 108
Pringle, J H "Avulsion of Spine of Tibia." *Ann Surg* 1907 46, 169
Jones, Robert and Smith, S. Alwyn. "On Fractures of the Tibial Spine" *Brit J Surg* 1913 1 70.

fracture of both condyles with considerable displacement Almost perfect reduction was secured by simple traction and manual compression the limb then being supported in a Thomas splint with simple skin traction An excellent functional result was regained with a good range of movement (Figs 1194 1195)

One condyle may be fractured as the result of valgus or varus strain the separated condyle being displaced upwards with resulting genu valgum if the fracture is of the lateral condyle or genu varum if it involves the medial condyle It is usually still more easy to correct the displacement by traction and direct manipulative compression than in bicondylar fractures. Sometimes however there is rotatory displacement Certainly if manipulative

Fig 1194

Fig 1195

Fracture of both condyles of the femur reduced manually and immobilised in a Thomas splint with skin-traction.

procedures fail to secure perfect replacement there should be no hesitation in exposing the lower end of the femur replacing the condyle with accuracy, and fixing it in a position with a long screw It is usually necessary to expose the joint surfaces in order to be sure that exact reposition has been gained but with perfect aseptic technique this does no harm

In one unusual case shown in Figures 1196-1197 the lateral condyle was fractured by direct violence and the patella being rotated through 90 degrees, was driven edgewise into the femur with its lateral margin forced into the articular surface and splitting off the condyle just as if a blunt chisel had been hammered in The patella itself was damaged so seriously that it had to be excised The condylar fragment of the femur and the other comminuted fragments were replaced accurately and fixed with screws The quadriceps tendon was repaired and excellent function was regained

backwards on the fixed tibia [1, 2] It is said that the spine may also be sheared off by impact of the margin of the femoral condyle in rotation stresses on the joint but if the fracture is exposed by opening the joint there is no evidence that the articular cartilage of the condyle has been bruised Moreover the fragment has obviously been pulled out of the tibia leaving a depressed crater which could not have been produced by shearing strain and it is displaced upwards and forwards by recoil of the cruciate ligament which is still attached to it

The tibial spine may also be displaced outwards by pull of the anterior horn of the lateral cartilage The displacement of the bone fragment causes limitation of the terminal degrees of extension, and the clinical features may suggest injury to one of the semilunar cartilages The diagnosis is established by the history of rapid swelling of the joint the clinical signs of hæmarthrosis and the radiographic evidence (Fig 1212) It may be possible to reduce the displacement by manipulation of the joint under anæsthesia but if radiographs do not show accurate replacement operative reduction is advisable An incision is made to the lateral side of the ligamentum patellæ the anterior horn of the external cartilage is divided [3] and the fragment is pressed into the bed from which it has been avulsed Reduction is usually stable and internal fixation is not needed The knee is immobilised for six weeks by a plaster cast in a position somewhat short of full extension Quadriceps exercise is practised regularly, and flexion movement of the joint is then regained by active exercise

DISLOCATION OF THE KNEE JOINT

Complete rupture of the medial lateral or cruciate ligaments of the knee must be associated with momentary dislocation Less frequently direct violence applied to the head of the tibia or indirect twisting or hyperextension strain causes more severe injury and the tibia is dislocated backwards forwards or laterally and does not slip back into position spontaneously [4-7] Not only are the ligaments ruptured but the capsule is extensively torn the semilunar cartilages may be displaced and chip fractures of the tibial spine tibial tuberosities or femoral condyles may occur As a rule reduction is accomplished quite easily by traction and direct pressure over the displaced bones The after treatment is that of the associated rupture of the cruciate and medial or lateral ligaments, namely immobilisation in a slightly flexed position for not less than three months and regular quadriceps exercise Weight bearing in an unpadded plaster cast is usually safe after four or five weeks (Figs 1213 1214)

Dislocation with interposition of capsule—Sometimes the dislocation cannot be reduced by manipulation because the femoral condyle is driven through a short tear in the capsule and gripped like a button in a button hole A flap of capsular tissue is interposed between the articular surfaces

Blaisdell, F E. Fractures of Tibial Spine Arch. Surg 1922, 5, 561
Clarke H O "Fractures of Tibia in ... Knee" Proc Roy. Soc Med (Section Orthopædics), 1933 28, 1035.
Kath, P B Fractures of Spine of Tibia. J Bone Joint Surg 1929 10, 607.
Ritter H H "Dislocation of Knee Joint." J Bone Joint Surg 1932, 14 101
Robbins, F R. "Forward Dislocation of Knee" Ann. Surg., 1932, 95, 206.
Patterson, R. H "Anterior Dislocation of Knee Joint." Ann Surg., 1934 99, 6..1
Cornell, H. E., and Aldredge R. H Complete Dislocations of the Knee Surg. Gyn. Obstet 1937 64, 94

Fig 1196

Fig 1197

Unusual fracture of condyle of the femur with interposition of the patella

As the result of direct violence the patella was rotated through 90 degrees and its lateral margin was driven into the femur splitting off the condyle The patella itself was so damaged that excision was needed. The condylar fragments were fitted together and fixed by stainless-steel screws. (*Operation by M. H. Osmond Clarke.*)

Fig 1213

Fig 1214

Open dislocation of the knee joint

A forward dislocation of the knee joint was associated with rupture of skin and deep tissues over the femoral condyles in the popliteal space. The wound was excised, the dislocation reduced, the joint immobilised and the muscles redeveloped. An excellent recovery was made after treatment by my colleague J R Armstrong of London.

DISPLACEMENT OF THE LOWER FEMORAL EPIPHYSIS

The epiphysis at the lower end of the femur may be separated from the shaft by violent hyperextension injury and when this happens the epiphysial fragment is usually tilted forwards in front of the femoral shaft the displaced position being maintained by the gastrocnemius which is the only muscle attached to it Typical displacement is shown in Figure 1198 This injury is much more easy to treat than supracondylar fractures of the femur in adults All that is needed is to apply traction and then flex the joint to just beyond the right angle pressure being applied over the front of the knee so as to push the epiphysis back. The shape of the separated surfaces is such that they fit accurately together and if the knee joint is immobilised in the flexed position reduction is stable The limb should be supported for eight weeks by a plaster slab over the front of the thigh and leg (Fig 1199)

In many ways this injury is comparable to supracondylar fractures of the humerus in children The displacement is to be reduced by flexing the joint after traction has been applied—but *only* after traction has been applied The flexed position must not be forced because there is such swelling around the joint that fixation in too much flexion may compress the popliteal vessels and endanger the circulation of the limb

There is particular danger of vascular complication in displacements of the lower femoral epiphysis exactly as there is in similar injuries of the lower end of the humerus because the popliteal vessels are stretched over the back of the lower margin of the diaphysis Injury to the artery may cause vasospasm with ischæmic contracture of the leg and foot There may even be such a degree of vascular injury as to cause thrombosis of the popliteal vessels with gangrene of the foot Care must obviously be taken to apply traction before flexing the joint and not to flex the joint too much It usually suffices to immobilise the limb in the right-angled position with an anterior plaster slab held in place with a crêpe bandage applied so lightly *as to exert no pressure in the popliteal space (Fig 1199) After about six* weeks the plaster cast may be discarded and movements of the knee joint are then regained by the patient's own active exercise Recovery should be complete within about six months

Unusual displacements of the lower femoral epiphysis—The usual displacement has been described—the epiphysis is tilted and displaced forwards But occasionally there may be displacement in other directions There may be lateral displacement of the epiphysis Very occasionally as shown in Figure 1201 the lower femoral epiphysis may be displaced backwards after manipulative reduction the limb should then be immobilised in a Thomas splint in the extended position

Arrest of growth after displacement of the lower femoral epiphysis—Traumatic separation and displacement of an epiphysis seldom interrupts growth because the line of injury is in the metaphysis *It is usually only a* crushing injury of the epiphysial line that causes arrested growth but Figure 1202 shows that deformity can sometimes arise from interference with growth in separations of the lower femoral epiphysis even when there is no clear evidence of crushing of the epiphysis

In this respect there is a close analogy between dislocation of the knee joint and of the elbow joint. In lateral dislocations of the elbow joint there may be interposition of capsule on the inner side, inclusion of the epicondyle of the humerus with ulnar palsy from traction injury. In *medial* dislocations of the knee joint there may be interposition of capsule on the outer side, inclusion of the styloid process of the fibula and lateral popliteal palsy from traction injury.[1] In neither case can the dislocation be reduced until the flap of tissue has been hooked out of the joint.

The postero-lateral dislocation of the knee joint shown in Figures 1215-1217 was sustained by a Czech pilot.[2] Repeated manipulation failed

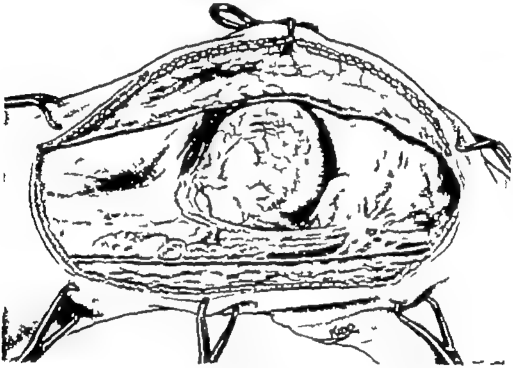


FIG. 1215

Dislocation of the knee joint with interposition of capsule and quadriceps expansion (see Figs. 1216-1217).

to reduce the dislocation. The backward displacement was easily corrected but no matter what pressure was applied the joint space remained wide on the inner side and on attempting to force reduction there was dimpling of skin over the medial joint line from the pull of underlying tissues imprisoned in the joint. Operative reduction was necessarily delayed for over two months because the initial violence drove the medial femoral condyle so hard against overlying skin that an area lost its blood supply and an ulcer developed—a trophic sore from pressure by bone on the deep surface of the skin. At operation the medial femoral condyle and its articular surface were visible as soon as skin and fascia were divided, the medial ligament, capsule and quadriceps expansion being tucked into the joint. Six months later, after immobilisation of the joint in plaster with

[1] Watson-Jones, R.: "Styloid Process of the Fibula in the Knee Joint with P[illegible]" *J. Bone Joint Surg.*, 1931, 13, [illegible].

[2] Clarke, H. Osmond: "Dislocation of Knee Joint with Capsular Interposition" [illegible] *Med.* (Section of Orthopaedics) 194[illegible], 35, 759.

Fig 1198
Typical displacement of epiphysis.

Fig 1199
After reduction of displacement

Fig 1200
Four years after reduction

Typical displacement of lower femoral epiphysis

Typical displacement of the lower femoral epiphysis (Fig 1198) The displacement was completely reduced by traction and flexion (Fig 1199). Four years later it is evident that there has been no interference with epiphysial growth; recovery was complete (Fig 1200).

Fig 1216

Postero-lateral dislocation of the knee joint. Manipulative reduction proved impossible. Widening of the joint space on the inner side shown in this radiograph and the clinical sign of dimpling of skin over the inner side during manipulation, confirmed the diagnosis of capsular interposition (see Fig 1215)

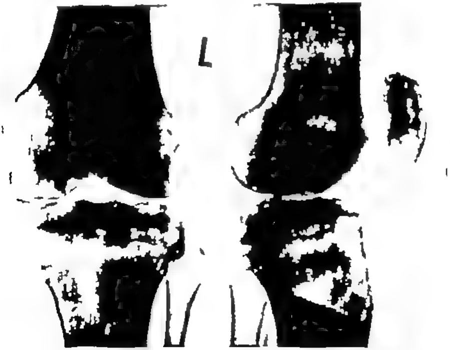


Fig 1217

Traumatic dislocation of the knee joint with interposition of capsule on the medial side

Same case as Figures 1215 and 1216 after operative reduction. After three months immobilisation in plaster intensive quadriceps exercise and development of joint movement, the patient resumed full duties.

Fig. 1201

Unusual displacement of the lower femoral epiphysis.

Fig. 1202

One year after reduction.

Fig. 1203

Normal knee for comparison.

Unusual displacement of the lower femoral epiphysis.

The injury occurred from a motor accident. Backward displacement is unusual (Fig. 1201). In displacing backwards the posterior part of the epiphysial line was evidently crushed; it fused prematurely and caused slight flexion deformity (Fig. 1202). Compare the injured knee joint with the normal knee (Fig. 1203).

whole cartilage is displaced centrally and the joint is therefore locked 2) posterior horn tears and tears of the central free margin in which a small pedunculated fragment is displaced and the joint does not lock.

Clinical features of bucket handle tear of the medial cartilage—The classical history of a torn medial cartilage is elicited when the lesion is of the bucket-handle type The patient sustains an abduction lateral rotation strain of the tibia on the femur Immediate severe pain over the medial side of the joint is often accompanied by a tearing sensation The joint locks in the semiflexed position and extension movement is limited not only by pain but by an elastic resistance Within a few hours the joint swells After several days the range of movement increases but the terminal degrees of extension remain limited and even if the joint looks straight to the surgeon it does not feel straight to the patient A history of sudden unlocking is sometimes but not always given Within three or four weeks the pain disappears the swelling subsides and the joint seems to be normal Some weeks or months later repeated stress of the same type causes recurrent locking pain and effusion On this occasion the disability is of shorter duration Every time the cartilage is displaced reactionary swelling and pain become less marked Finally the patient may suffer locking and unlocking of the knee almost without interference with his normal routine With such a history with tenderness over the joint line in front of the medial ligament and radiographic evidence excluding loose body formation the diagnosis of a bucket-handle tear of the medial semilunar cartilage is seldom beyond doubt If the last few degrees of extension movement are limited by an elastic block it is clear that the loose fragment or even the whole cartilage is still displaced across the joint and is lying in the intercondylar region

Clinical features of posterior horn tear of the medial cartilage—When the lesion of the cartilage is not a longitudinal split with displacement of a fragment so large that it locks the joint but a localised tear which separates a small pedunculated fragment or loosens the posterior horn the classical history is not elicited The injury again arises from abduction lateral rotation strain of the flexed joint and pain is usually on the medial side but there is no locking and unlocking no localising tenderness and sometimes no effusion The patient reports that the joint feels unstable It feels as if the joint is about to lock but it never actually does so It tends to give way especially when going down stairs and this sensation of insecurity may recur many times a day There may be a sensation of something slipping but localisation is so difficult that the patient usually puts his hands on each side of the joint and says "it is in the middle" The history is characteristically vague and with the exception of one important sign clinical examination may not help to establish the diagnosis The sign was described by McMurray [1] [2] and is of the greatest value Without it the diagnosis may be overlooked in a group of cartilage injuries which are no less common than bucket handle tears—or alternatively the surgeon is driven to an "exploration of the knee" which often fails to disclose the lesion because it lies so far back that it cannot be seen until the cartilage has actually been removed

McMurray T P "Diagnosis of Internal Derangements of the Knee" Robert Jones Birthday Volume Oxford Med Pub 1928 303
McMurray T P "A Practice of Orthopædic Surgery" Edward Arnold & Co., 1937 5

CHAPTER XXVI

INJURIES OF THE KNEE

Redevelop the quadriceps: exercise for five minutes hourly throughout the day This instruction is of the utmost importance in the treatment of every knee joint injury. Manipulations and operations may be performed and the joint may be immobilised but no matter what other treatment may be needed, active non weight bearing exercises must be practised. Simple strains traumatic synovitis rupture of ligaments tearing of semilunar cartilages fractures into the joint—almost every injury of the knee should be treated from the first day by regular quadriceps drill. Injuries such as open wounds of the joint or traumatic hæmarthrosis which may be complicated by infection or continued hæmorrhage are the only exceptions and even in these cases quadriceps exercise should be practised after two or three weeks

Wasting of the quadriceps muscle is itself a source of disability. The knee joint is imperfectly protected from the twists and strains of weight-bearing. Repeated stretching of ligaments and nipping of synovial fringes cause recurrent effusion and the swelling may persist for many months. If such muscle wasting is accompanied by rupture of ligaments or a tendency to arthritis the disability is still more serious. It is seldom relieved by the operative construction of new ligaments because if the muscle-guard is lost the ligaments stretch as soon as weight bearing is resumed. It is not relieved by the use of a knee cage because the protection of such an appliance is inadequate and still more wasting of muscles is encouraged. But if the quadriceps can be fully redeveloped relaxation of ligaments and early osteoarthritis cause little or no incapacity. The joint is protected it is no longer strained whenever weight bearing is attempted and the symptoms subside

Muscle wasting occurs as a direct consequence of injury of the knee joint. An almost total reflex inhibition of the quadriceps may be observed, and the muscle is completely flaccid—it might well be paralysed for no flicker of active contraction seems possible. Wasting is unusually rapid and the volume of the muscle disappears far more rapidly than it can subsequently be regained. Treatment is therefore urgent. The inhibition must be overcome as soon as possible by the patient's own exercise. This can be practised without weight-bearing without movement of the joint and without aggravation of the injury. Massage and faradism are relatively useless because the treatment is purely passive it does not restore voluntary control it encourages the patient in his apathy and it is possible only for limited periods. Moreover it is not enough to advise the patient vaguely to practise exercise. Specific instruction is essential. Quadriceps contraction must be demonstrated. The muscle should be made as tight as possible and the contraction be sustained. The limb is raised against gravity with the knee

Test for posterior horn cartilage lesions—The surgeon stands on the side of the injured knee places the fingers of one hand over the joint line and with the other hand firmly grasps the foot The knee is flexed fully so that the heel is almost touching the buttock The tibia is then rotated inwards and outwards on the femur and is moved sideways from the adducted to the abducted position and back again If the tear is at the posterior limit of the cartilage the loose fragment can be felt slipping between the femoral condyle and tibial tuberosity, and the resulting click is localised to the postero medial compartment of the joint If this manœuvre fails to disclose a typical click, the leg should be rotated and abducted at the knee while the joint is slowly extended An easily palpable and often audible click may then be produced as the pedunculated fragment slips between the femoral condyle and tibial tuberosity The more extended the knee at the moment that the click is produced the farther forward in the cartilage is the tear Care must be taken to differentiate this click from the posterior horn cartilage click which is normal in the relatively lax joints of children and which sometimes can be elicited in adults even in the uninjured knee The thin quality of this click the fact that it is not audible that it is unaccompanied by any jerking movement between the femur and tibia and that it does not reproduce the pain which had been experienced every time that the knee gave way all indicate that it arises from laxity of the cartilage within normal limits and not from a loose fragment or tearing of the posterior horn from its peripheral attachments

Clinical features of torn lateral cartilage—Bucket-handle tears and detachment of pedunculated fragments from the posterior horn or from the central free margin of the lateral cartilage occur less commonly than in the medial cartilage but the frequency is nevertheless greater than is generally recognised This lesion is the result of an adduction medial rotation strain of the tibia on the femur and pain is usually localised to the lateral side of the joint Tenderness is absent from the medial side but may be elicited on the lateral side over the anterior horn of the cartilage the middle of the lateral ligament or the posterior horn of the cartilage according to the site of injury Bucket-handle tears with displacement of the fragment always account for limitation of the terminal degrees of extension and sometimes cause typical locking Posterior horn lesions are recognised by the cartilage click elicited when the fully flexed tibia is adducted medially rotated and gradually extended Anterior horn lesions often cause very loud clicking audible at a distance occuring as the joint is actively extended and usually in the position of about twenty degrees short of full extension This loud click or clunk is also the characteristic feature of congenital disc cartilages which represent the persistence of the discoid form of cartilage seen in the knee joints of certain apes and reproduced in the early stages of development of the human fœtus by a plate of mesodermal tissue [1]

Treatment of torn semilunar cartilage—*Treatment of first injury*—The peripheral attachment of a cartilage to the capsule of the joint is well supplied with blood vessels and tears in this region can unite if the joint is suitably immobilised at the time of the original injury Tears of the

[1] Fairbank, H A T "Internal Derangement of Knee in Children and Adolescents" (sixty three cases including congenital discoid cartilage absent posterior half of cartilage "reversed cartilage attached medially etc.), *Proc Roy Soc Med* (Section of Orthopædics) 1937 30, 427

straight and after a few days it is raised against the resistance of a flat-iron or a brick suspended over the ankle (Fig 1204) The exercise should be repeated every hour for not less than five minutes Boredom may be relieved by practice to the beat of music Such treatment prevents wasting of the thigh even when the limb is completely immobilised in splints or plaster Even if the muscle is already wasted it is possible by quadriceps

FIG. 1204

Active quadriceps exercise is of the greatest importance in all injuries of the knee joint.

drill and by the non weight bearing exercises of cycling and swimming to regain normal volume and tone of the muscle within six or eight weeks

The injuries to be considered in this chapter include—

Internal derangements of the knee joint

- Traumatic synovitis and hæmarthrosis
- Injury of the medial lateral and cruciate ligaments
- Fracture of the tibial spine
- Injury of the semilunar cartilages
- Loose bodies in the knee

Injuries of the extensor mechanism of the knee

- Avulsion of the quadriceps
- Fracture of the patella
- Avulsion of the ligamentum patellæ
- Injuries of the tibial tubercle and Schlatter s disease

Fractures of the tibial tuberosities

avascular cartilage itself seldom unite whether the knee is immobilised or not and recurrent displacement of the loose fragment is then inevitable It is wise after a first injury to immobilise the knee on a splint or plaster slab *for about four weeks in the hope that the lesion may be in the peripheral* attachment Operative treatment is advised only when recurrent locking proves that this is not so

A torn cartilage should of course be removed as soon as the diagnosis is certain, but let us emphasise that the diagnosis must be certain At first, many injured knee joints seem to show the signs of a torn cartilage whereas in fact the injury has been no more than a traumatic synovitis Moreover it is never wise to operate on a 'hot knee in which there is acute effusion and considerable traumatic reaction No harm comes from allowing time for the reaction to settle and moreover many unnecessary operations will thus be avoided After a severe wrench of the joint with acute synovitis there is often limitation of extension which may be misinterpreted as a block to movement from displacement of the cartilage and yet this sign disappears within two or three weeks after simple rest Only when the *diagnosis of a torn cartilage is quite certain should* an operation be arranged and in all other cases conservative measures are indicated [1 4]

Treatment of recurrent cartilage displacement—If the cartilage has been displaced on more than one occasion no doubt remains as to the necessity for operative treatment The disability cannot be cured by immobilisation or by manipulation and any attempt to prevent displacement by the fitting of a knee cage or other surgical appliance is uncertain and unsatisfactory If the cartilage is not removed the recurrent trauma of repeated displacement leads ultimately to osteoarthritis of the joint

Treatment of torn cartilage in an osteoarthritic knee—It is sometimes said that operative treatment is not indicated for recurrent cartilage displacement if osteoarthritic changes are present in the joint This view is entirely unjustified Every time that the cartilage is displaced the joint is traumatised and the arthritis is aggravated

Treatment of torn cartilage with ruptured ligaments—It has also been suggested that excision of the cartilage is not advisable when the cruciate ligaments are ruptured This view is equally unjustified Far from refusing to excise the torn cartilage it is the duty of the surgeon to make certain that both cartilages are not torn and that both may need to be excised

Manipulative treatment—Recurrent displacement of a torn cartilage cannot be cured by manipulation Successful results have often been claimed especially by unqualified practitioners but the disabilities they have relieved by manipulation have not been from torn cartilages they may *have been from adhesions in the region of the cartilage* from recurrent

Regenerated cartilage—The patient who fears that loss of the function of the semilunar cartilage will cause weakness of the joint may be reassured not only by the experience of surgeons but also by that of experimental pathologists. A growth of fibrous tissue from the deep layers of the capsule produces a new "cartilage" which replaces the old one and resembles it in contour and position, though not in size mobility or vulnerability to further injury A regenerated cartilage is easily distinguished from a normal cartilage by its tri-radiate shape and white colour Very occasionally a regenerated cartilage is fractured once more with the separation of a pedunculated or bucket-handle fragment, and the surgeon who operates for recurrent disability after an earlier operation and finds a split cartilage must not jump to the conclusion that a previous surgeon had completely failed in his task of removing the cartilage.

Gliona, A "Regeneration of Internal Cartilage after Operation." *Brit. J Surg* 1931, 19, 302.
Bruce J and Walmsley R. "Replacement of Cartilages after Excision." *Brit. J. Surg* 1937, 25, 17
Goldenberg, R R *Refracture of Regenerated Semilunar Cartilage*" *J Bone Joint Surg* 1935, 17 1054

TRAUMATIC SYNOVITIS AND HÆMARTHROSIS OF THE KNEE JOINT

Traumatic synovitis—A strain or twist of the knee may cause synovial effusion with filling of the joint hollows distension of the suprapatellar pouch and floating of the patella which can be made to tap against the femoral condyles The joint should be bound firmly with crêpe bandage and if there is a marked effusion immobilised on a back splint in the position of almost full extension Exercise of the quadriceps muscle should begin at once and be continued hourly throughout the day Weight bearing is resumed in a few days and the back splint is discarded after ten days Recovery should be complete within two or three weeks

Recurrent synovitis—If the muscles are allowed to waste recurrent synovitis may develop particularly in middle aged patients whose joints show a tendency to degenerative arthritis Weight bearing activity should be reduced until normal muscle control has been regained by regular quadriceps drill Injury to one of the semilunar cartilages with recurrent displacement of a pedunculated fragment must be excluded Tuberculous synovitis is distinguished by the pulpy, dough like sensation of synovial thickening Syphilitic synovitis[1] is differentiated by the symmetrical involvement of both knee joints the Wassermann reaction and the response to anti-syphilitic treatment

Traumatic hæmarthrosis—A severe blow or twist may tear the blood vessels of the synovial membrane and cause hæmarthrosis Hæmorrhage into the joint also accompanies every fracture of the tibial spine and of the patella and it may complicate tears of the peripheral part of a semilunar cartilage and operations for removal of the cartilage The joint fills rapidly and is swollen within an hour whereas in simple synovitis the swelling reaches its maximum only after six or eight hours The joint contents feel firmer and less fluid than in synovitis pain is greater and there is a febrile reaction The temperature rises to 100 or 102 F and the joint feels hot The blood should be aspirated the joint firmly bound with crêpe bandage and immobilised on a back splint Quadriceps drill is begun after ten or fourteen days when the danger of recurrent hæmorrhage is over

INJURIES OF THE LIGAMENTS OF THE KNEE JOINT

The medial ligament of the knee joint may be sprained or completely torn[2,3] It may be avulsed from its femoral attachment by an abduction strain of the extended knee Less frequently the broad tibial insertion of the ligament is avulsed and sometimes the injury is localised to the deep fibres at the joint level where the semilunar cartilage is attached The diagnosis is made by the swelling and ecchymosis tenderness localised to the site of injury pain when the joint is strained into valgus and effusion into the joint The terminal degrees of extension movement are sometimes restricted and during the first fourteen days before the limitation of movement has disappeared it may be difficult to differentiate a simple sprain from a combined ligament and cartilage injury If the injury is a true sprain no more than a few fibres are torn and lateral stability of the joint is normal The

[1] Todd, A. H "Syphilitic Arthritis." *Brit J Surg* 1927 14 200
[2] Palmer I "On Injuries to Ligaments of the Knee Joint." *Act chir scand* 1938 81 Supp. 53.
[3] Horwitz, M T "Surgical Anatomy of Ligaments of Knee Joint" *Surg Gyn Obstet* 1938 67 287

synovitis with hypotonicity of the quadriceps or from early arthritis of the knee joint with loss of muscle control Adhesions can be cured by manipulative treatment and injured knee joints are always improved by simple redevelopment of the quadriceps—but there is little more than this to the work of osteopaths and other manipulators in their treatment of this joint

Technique of excision of semilunar cartilage—A pneumatic tourniquet is applied and the leg is hung over the end of the table with the knee flexed The medial cartilage is removed through an oblique incision two inches in length over the antero medial compartment of the joint If the incision

FIG 1218

Excision of medial semilunar cartilage. The cartilage must be grasped with a strong, deep-toothed clamp a retractor must be held by an assistant so that the junction of cartilage and capsule is displayed The peripheral attachment is divided until the cartilage slips into the intercondylar space The posterior horn can then be seen and the whole cartilage removed through one incision.

begins near the patella and passes downwards and inwards a small branch of the saphenous nerve may be divided causing anæsthesia of the skin over the tibial tubercle and sometimes persistent tenderness of the scar from nerve bulb formation [1] An incision that begins over the margin of the femoral condyle and passes downwards and outwards avoids injury to the nerve and gives equal access to the joint The capsule and synovial membrane are divided in the same line *The cartilage must be removed whether the split can be seen or not* Localised tears or peripheral detachment of the posterior horn cannot be seen until removal of the cartilage is almost complete All doubts should have been resolved before the operation was begun The diagnosis should have been made with such confidence that the cartilage is removed right back to the posterior horn even if on first inspection it appears

[1] Naughton Dunn. "Injury of the Knee Joint." *Brit med J.*, 1931 2, 699. *Lancet*, 1934 1 1267

just below the groin The knee joint is flexed 30 degrees and the head of the tibia is pushed backwards for ruptures of the anterior cruciate ligament and pulled forwards for ruptures of the posterior cruciate ligament Immobilisation should be continued for not less than three months

FIG. 1209

Testing for rupture of the anterior cruciate ligament. There is no excessive forward mobility of the tibia and the ligament is therefore uninjured.

FIG. 1210

Testing for rupture of the posterior cruciate ligament. Excessive backward mobility of the tibia shows that the ligament is torn.

The incapacity from untreated ruptures of the cruciate ligaments with persistent instability may be reduced by constructing new ligaments from fascia lata The fascia is twisted into firm cords and passed through holes drilled in the femoral condyles and tibial tuberosities so that they cross in

to be normal The anterior horn is detached from the tibia It is gras with a specially deep-toothed cartilage clamp This instrument an retractor held beneath the medial ligament of the joint so that the junc of ligament and cartilage is clearly defined are essential (Fig 1218) W the surgeon has a confident grasp of the cartilage by the clamp in one ha and when without any doubt he can see the line of demarcation betw cartilage and capsule the peripheral fibres of attachment are cut by vert strokes of the scalpel the cartilage meanwhile being pulled forwards u it slips across the joint into the intercondylar space The attachment of posterior horn to the tibia can then be seen and divided The whole cartil must be removed including the posterior horn [1] It is unwise to us tenotomy knife because the blade may ca break off in the back of the joint bu Smillie knife is admirable provided only t the margins to the cutting blade are blun and not sharp-pointed [2] It must alway remembered that as well as the m popliteal vessels, the geniculate arteries just behind the menisci and that a tenoto pointed knife or sharp narrow chisel dri carelessly into the back of the knee joint m perforate these arteries and cause aneurism [3-]

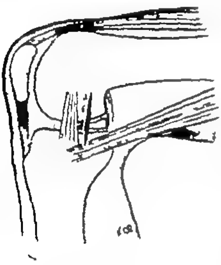


FIG. 1219

If through an error of technique the posterior horn is left in the back of the joint it is essential to remove it through a second incision over the posterior compartment.

Excision of the posterior horn of medial cartilage—If by an error of techni the back of the cartilage is not complet removed through the anterior exposure (i let it be emphasised that this is alw possible) a second incision should at once made behind and parallel to the me ligament the capsule and synovial m brane being divided in the same line (F 1219) A retractor is held over the mar of the ligament and the posterior capsule of the joint is retracted T back of the cartilage with its posterior horn is thus removed without v great difficulty

Excision of lateral cartilage—The technique of operation is the same for the excision of the medial cartilage but if a second incision is made removal of the posterior horn care must be taken not to damage t popliteus tendon which lies in contact with the cartilage

Post-operative treatment after excision of the cartilage—After operati the knee should be protected by means of a plaster slab bound to the li with a crêpe bandage The degree of joint reaction depends upon t number of times the cartilage has previously been displaced If an operati is performed after a first or second displacement considerable effusion m

Smith Alwyn Sidelight on Knee Surgery Robert Jones Birthday Volume *Oxford Med Pub.*, 1928
Smillie I S Injuries of the Knee Joint. Edinburgh E & S Livingstone Ltd 1951
Fairbank, T J Jamieson, E S Vaughan-Jackson, O Smillie I. S. and Osmond-Clarke H Traum Aneurism Complicating Lateral Meniscectomy" *J Bone Joint Surg* 1951 33-B, 243.
Fairbank, T J and Jamieson E A Complication of Lateral Meniscectomy (false aneurism of the lat inferior geniculate artery) *J Bone Joint Surg* 1951 33-B, 66
Ross, W T Injury t the Popliteal Artery during Meniscectomy" *J Bone Joint Surg* 1951 33-B,

FIG. 1220
Double bucket handle tear.

FIG. 1221
Triple bucket-handle tear

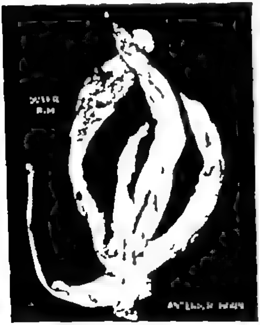


FIG. 1222
Quadruple bucket handle and early fifth tear

FIG. 1223
Double bucket handle tear of congenital disc cartilage

Multiple cartilage injuries

These examples of multiple cartilage injury emphasise the importance of always removing the whole of an injured cartilage. There can be no defence for removing only the anterior half, or only the bucket handle part that is displaced centrally across the joint

Fig. 1234

Comminuted fracture of the patella in a patient aged sixty-eight.

Fig. 1235

Radiograph after excision of patella and suture of quadriceps tendon.

Fig. 1236

Fig. 1237

Power of the knee and range of movement two months after comminuted fracture of patella treated by excision of bone and suture of tendon (same case as in Figs. 1234 1235).

FIG. 1224

FIG. 1225

Concealed second bucket handle tear

When the cartilage is first exposed it appears that the lesion is a simple bucket handle tear (Fig. 1224). Only after the whole cartilage including the peripheral fragment is excised does the second bucket handle split appear (Fig. 1225). If no more than the centrally displaced fragment had been removed, there would have been persistent disability.

FIG. 1226

FIG. 1227

Concealed second tear in the posterior horn

Bucket handle tear with secondary posterior horn tear of the free margin of the peripheral fragment. The secondary lesion cannot possibly be seen until the whole cartilage has been excised. The peripheral fragment must always be removed as well as the central fragment.

patella is sutured with catgut mattress stitches A plaster cast is applied with the joint almost fully extended. Weight bearing may be resumed within a few days and quadriceps exercise is practised regularly The plaster cast is discarded after two months and flexion movement is regained by active exercise practised for a few minutes hourly throughout the day

Suture with wire—Wire is sometimes used to encircle the patella or is passed through drill holes in the fragments but as a rule it is found to be less safe than catgut either because it snaps where the ends are twisted together or because the metal is too soft or is dissolved by ionisation. An excellent example is shown in Figure 1233 where the fragments of wire are scattered through the lower half of the thigh and there is displacement of no less than six inches between the fragments of the patella It is remarkable that nevertheless this man had being doing heavy manual labour for more than thirty years and made his first complaint when he developed tabes dorsalis Another example of the dangers of ionisable wire is seen in *Figure 1232 where one of the fragments of a wire suture separated and* became lost in the joint as a foreign body lying at the moment that this particular radiograph was taken in the posterior compartment

No matter whether wire or catgut or any other suture material is used *there is often difficulty in restoring a smooth articular surface and some* degree of roughening is almost inevitable, especially when the fracture is comminuted. An extreme example of the gross osteoarthritis that can arise in these circumstances is shown in Figure 1239 Even when there is much less displacement than this and the operation of suturing has been performed with every care the polished articular surface of the bone may still be scored with ridges of callus and creaking and grating in the patello-femoral compartment then causes osteoarthritis After operative suture with the immobilisation that is needed it is often difficult to regain flexion movement and this is still more difficult in middle aged and elderly patients in whom very often, there are already arthritic changes.

Indications for excision of the fractured patella—The best treatment for osteoarthritis confined to the patello-femoral compartment of the knee joint is excision of the patella [1] A comminuted fracture of the patella in a middle-aged or elderly patient usually causes osteoarthritis of this part of the joint It is still better therefore to excise the patella at the time of the fracture and thus avoid the complication The quadriceps tendon can be sutured so much more firmly after excision of the bone that external splinting is unnecessary Active movement and flexion exercises may begin within three or four weeks With carefully directed treatment normal movement is soon regained (Figs 1234-1238) The operation avoids the necessity *for prolonged after treatment* reduces the incapacity period from about twelve months to about four months minimises the danger of permanent stiffness of the joint and avoids the late complication of osteoarthritis of the knee Suture of the bone should be performed for fractures in young adults and excision reserved for fractures in middle-aged and elderly patients and for severely comminuted fractures in patients of all ages

Indications for excision of one fragment of the fractured patella—If a fracture of the patella lies near the upper or lower poles there need be no hesitation in excising the smaller fragment even in young patients Excision

be expected and six or eight weeks may elapse before recovery is complete If the cartilage has been displaced many times the reaction is slight and recovery is often complete within four weeks Rapid recovery is possible only if the tone of the thigh muscles is maintained The patient should be taught quadriceps drill before operation The day after operation attempts are made to overcome the reflex inhibition of the muscle Part of the weight is taken by the surgeon while the patient tries to elevate the limb with the knee straight With suitable encouragement and persuasion the patient takes more and more of the weight until quite suddenly the knack of contracting the muscle is regained Non weight-bearing quadriceps contraction is then continued for five minutes hourly throughout the day Flexion movements are begun after about fourteen days but weight-bearing should be deferred for at least two or three weeks and it is sometimes advisable to wait even longer The bearing of weight too early causes recurrent effusion and delays recovery

Importance of removing both fragments of a bucket handle tear of the cartilage—When the lesion is a bucket handle tear some surgeons content themselves with excision of the displaced central fragment the peripheral fragment being left undisturbed Very often however the bucket-handle tear is not the only injury and the peripheral fragment itself is torn If a cartilage has been displaced many times it is almost certain that there will be secondary lesions sustained at the time of the secondary displacements There may be a second bucket-handle split of the peripheral fragment detachment of a pedunculated fragment from the torn margin or loosening of the posterior horn These lesions are often concealed until the whole cartilage is out of the joint It is impossible to determine whether or not there are secondary lesions at the back of the joint just by pulling on the front end of the peripheral fragment Figures 1220 1227 are examples from a large series of multiple cartilage lesions which illustrate the impossibility of diagnosing the second lesion until the cartilage has been removed If all the fragments of a torn cartilage are not removed—two incisions being used when necessary—the symptoms that are characteristic of a posterior horn lesion often remain Although the joint may never lock it seems to the patient that it is about to lock the joint is insecure it gives way and symptoms persist until a second operation is performed for excision of the remaining fragment at the back of the joint

Cysts of the semilunar cartilage arise from mucoid degeneration of the cartilage substance possibly as a result of contusion of the cartilage from a direct blow or indirectly by vertical compression between the femur and tibia[1-4] The cystic area involves the peripheral part of the middle third of the lateral cartilage and very occasionally of the medial cartilage It is multilocular and gives rise to a swelling beneath the lateral ligament so tense that it is sometimes mistaken for a bony *exostosis* The size of the cystic mass may be anything up to two inches in diameter The diagnosis is easily made by precise localisation of the swelling which can be seen and felt It is the only tense swelling that is situated exactly in the middle of the lateral surface of the knee at the level of the joint line The patient

Ollerenshaw R. "Development of Cysts in Semilunar Cartilage," *Brit. J. Surg.*, 1921, 8, 409
Phemister, D. B. "Cysts of External Cartilage of Knee" *J. Amer. med. Ass.* 1924, 80, 593.
Bristow W. R. "Cysts of Semilunar Cartilages," Robert Jones Birthday Volume, 1928, 269
Taylor Hermon, "Cysts of the Fibro-cartilages of the Knee Joint" (with review of previously recorded cases), *J. Bone Joint Surg.* 1935 17 588

Fig. 1234

Comminuted fracture of the patella in a patient aged sixty-eight.

Fig. 1235

Radiograph after excision of patella and suture of quadriceps tendon.

Fig. 1236

Fig. 1237

Power of the knee and range of movement two months after comminuted fracture of patella treated by excision of bone and suture of tendon (same case as in Figs. 1234 1235).

Fig 1228

Cyst of lateral semilunar cartilage with tear of anterior horn separating a pedunculated fragment. After the cystic cartilage had been removed a second tear was seen at the posterior horn separating another pedunculated fragment (Fig 1229).

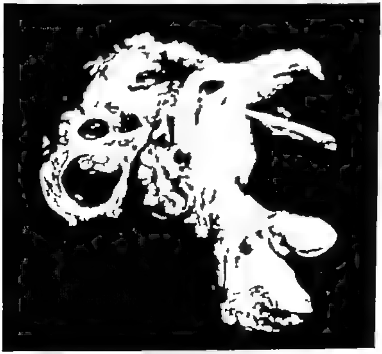


Fig 1229

Same specimen as in Figure 1228 After the cartilage had been removed a second tear involving the posterior horn was seen for the first time

of one small fragment has all the advantages and none of the disadvantages of total excision of the bone.

Excision of the patella with suture of quadriceps tendon—Through a straight vertical incision the fracture and the tear in the tendon are exposed and blood clot is evacuated from the joint. The fragments of the patella are shelled out by dissection close to the bone. It is then very easy to suture the tendon with strong catgut mattress sutures or with fascia. The upper and lower flaps should be overlapped and bunched together in the

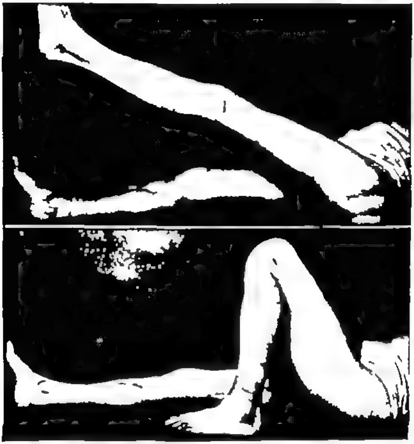


FIG. 1238

Movement of knee joint six months after excision of a fractured patella

gap from which the bone was excised. If this is done the final contour of the knee is surprisingly normal despite loss of the bone—at any rate in the extended position. Some flattening of the contour is usually evident when the joint is flexed to the right angle. The joint is bound firmly over several layers of wool and at first the limb is supported in plaster. Active flexion and extension exercises should begin after two or three weeks and weight bearing may be resumed after about six weeks. Recovery is usually complete within three or four months.[1]

Excision of patella fractured during manipulation of a stiff knee—If severe stiffness of the knee joint, arising for example in the treatment of a fractured shaft of the femur, is treated by manipulation under anæsthesia and the patella is unfortunately fractured, the best treatment is often to complete

[1] Scott, F. R. "Fractured Patella." C. nad. med. Ass. J. 1934, 31, 572.

complains of persistent aching pain but not of locking, giving way or recurrent swelling The whole of the cyst and the cartilage from which it is developing should be removed

Calcification and ossification of semilunar cartilage—Aching pain in the knee joint sometimes occurs from calcification of one or both semilunar cartilages a pathological process which possibly follows compression injury Two cases have been recorded of ossification of the lateral cartilage and two of ossification of the medial cartilage[1 2] giving rise to symptoms and radiographic appearances suggestive of loose bodies in the joint

Tears of both cartilages of one knee—When a knee joint has frequently been locked by recurrent displacement of a semilunar cartilage the patient has fallen and stumbled so often that he may also have torn the other cartilage of the same joint Careful study of the clinical history and physical signs has often made it possible to establish a pre-operative diagnosis of rupture of both cartilages Lambrinudi reported eight cases of dual lesions of both semilunar cartilages of the same knee[4] and many surgeons have now had similar experience in scores of cases

Torn cystic semilunar cartilage—It is useless to remove a cyst from the peripheral part of a cartilage without removing the cartilage itself because cyst formation will then recur Moreover the whole of the cartilage must be removed, including its posterior horn because tears of the central margin or posterior horn have often been sustained The mass of cyst developing beneath the tight lateral ligament tends to push the cartilage in towards the weight-bearing area of the joint and so predispose to splitting from weight-bearing strains Figure 1228 is an example of a cystic cartilage with a tear of the anterior horn When it was removed a second split of the posterior horn could also be seen (Fig 1229)

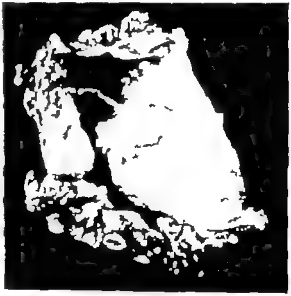


FIG 1230
Bucket-handle tear of congenital disc cartilage.

Bucket-handle tear of congenital disc cartilage—Even a congenital disc cartilage is not immune from injury The specimen shown in Figure 1230 was removed from the lateral side of the knee joint of a girl aged sixteen Movements of the knee had been accompanied by loud clicks and thuds for as long as she could remember but the disability had become much worse twelve months before operation when she fell playing lacrosse She had then sustained a longitudinal split of the congenitally abnormal cartilage

W tson-Jones, R., and Roberts, R. E. "Calcification, Decalcification and Ossification" (bibliography of calcification of semilunar cartilages, and report of two case of ossification in external cartilage). *Brit. J Surg* 1934, 21, 461.
Burrows, H. Jackson. "Two Cases Ossification in Internal Semilunar Cartilage." *Brit. J Surg* 1933 21 404.
Girdlestone, G R Calcification of Semilunar Cartilages." *Proc. Roy Soc Med* 1933 27 1268.
Lambrinudi, C "I jury to Both Semilunar Cartilages of Knee Joint." *Proc. Roy Soc Med.*, 1939 32, 635

the manipulation by flexing the joint to about the right angle, and then to excise the patella and suture the tendon. Exercise of the joint may be resumed within about three weeks. With such treatment fracture of the patella is no longer a serious surgical accident. Indeed fixation of the bone to the femoral condyles may have been the important cause of the stiffness and excision the one measure necessary for its relief.

Excision of comminuted stellate fractures of the patella—Even when a fracture of the patella has arisen from direct violence so that there is

FIG. 1239

Mal-united fracture of the patella

Grossly mal-united fracture of the patella with secondary arthritis of the patello-femoral compartment. It was treated by excision of the patella and suture of the quadriceps tendon. The result was satisfactory but not as good as it would have been after early excision.

comminution of the bone but no avulsion or upward displacement of the proximal fragments, it may still sometimes be wise to treat the injury by primary excision of the shattered fragments with repair of the quadriceps tendon. The damage to the articular surface may be so great that patello-femoral arthritis seems almost inevitable. At the same time there must be caution before deciding to excise the bone in these fractures. It is often surprising how excellent is the function regained after simple immobilisation of a comminuted fracture of the patella for three or four weeks with active movement thereafter. Moreover if arthritis of the patello-femoral joint does develop late excision of the bone is always possible and little will have been lost from the delay.

Excision for old compound fracture of patella—Figure 1240 is the

LOOSE BODIES IN THE KNEE JOINT

Loose bodies in the knee joint may arise from three sources 1) osteochondritis dissecans in which a fragment of articular cartilage and underlying bone is separated from the femoral condyle and less commonly from other parts of the articular surfaces 2) osteoarthritis of the knee with detachment or *fracture of marginal osteophytes* from the patella femoral condyles or tibial tuberosities, 3) chondrification of the synovial membrane with the formation of a large number of loose bodies The symptoms of recurrent *locking effusion and pain in the joint* may be identical with those of displacement of a torn semilunar cartilage and radiographic examination is necessary before operation is performed for a suspected cartilage injury (Fig 1231) An isolated loose body *should be* removed through a short incision over it Multiple bodies from synovial chondrification may require synovectomy

Fig 1231
Loose bodies in the knee joint.

RUPTURE OF THE EXTENSOR APPARATUS OF THE KNEE JOINT

Formerly it was not doubted that the patella was an essential element of the knee joint Whether it was believed to be a sesamoid bone for protection of the quadriceps tendon, or a pulley mechanism for augmentation of the power of the muscle by holding its tendon in front of the axis of movement of the joint the functional importance of the bone was accepted Nevertheless Brooke[1,2] maintained that the existence of a patella in the *knee joint was the result of phylogeny alone and that in man it served* no useful function In the evolution of rapidly moving animals it is retrogressive The bone is massive and well developed in sloths and moles small in foxes and leopards and absent in fast moving kangaroos Experience in the human shows that the knee joint is just as safe after excision of the patella with suitable repair of the quadriceps tendon as it was before I have one patient who writes regularly from the mountains of Wales Scotland, Switzerland and Austria where for many years she has climbed including difficult rock climbing after excision of both patellæ for osteochondritis of the articular surfaces

Brooke R "Removal of Patella for Simple Fracture" *Proc Roy Soc Med* 1937 30, [illegible]
Brooke R "*Treatment of Fractured Patella by Excision—a Study in Morphology and Function*" (report of thirty cases of primary excision) *Brit J Surg* 1937 24, 733.

radiograph of a knee joint twelve months after an infected compound fracture of the patella The bone was solidly fixed to the femoral condyles by dense fibrous tissue so that the knee was completely stiff The patella was excised the joint manipulated into almost full flexion and the quadriceps tendon repaired Despite slight recurrence of infection which necessitated immobilisation for one month the patient had no difficulty in regaining movement Within six months the joint could be flexed through 150 degrees and there was a full range of extension movement

FIG. 1240

FIG. 1241

Old infected compound fracture of the patella with complete stiffness from fibrous ankylosis to the femoral condyles (Fig 1240) The bone was excised, the joint flexed and the quadriceps then repaired (Fig. 1241) An almost normal range of movement of the knee joint was regained in a most difficult case

Un united fracture of the patella—An un united fracture of the patella of many weeks or months duration should usually be treated by excision of the bone fragment and repair of the quadriceps tendon with as much correction of muscle retraction as possible Some surgeons have used strips of fascia lata but the simpler method of catgut suture is usually better

AVULSION OF THE LIGAMENTUM PATELLÆ FROM THE PATELLA

Avulsion of the ligamentum patellæ from the patella is again a rupture of the quadriceps tendon and the tear involves not only those fibres which are attached to the patella itself but the whole of the lateral quadriceps expansion Active extension movement is therefore lost and the patella i displaced upwards by retraction of the quadriceps muscle If the rupture is not repaired by early operative suture the hæmatoma below the lower pole of the patella undergoes ossification and the new bone either fuses to the patella or becomes scattered—myositis ossificans traumatica—this depending upon whether or not the knee joint is immobilised If the tendon is sutured within a few days of injury no more than a few spicules of bone

The quadriceps muscle is not in fact inserted into the upper border of the patella so much as into the tibia by means of the tendon which passes over and round the patella. Quite apart from the slender fibres which pass over the front of the bone there are sufficient strong fibres on each side of it to extend the knee joint and the integrity of the quadriceps tendon need not be destroyed by excision of the patella. It has long been recognised that there are two types of fracture of the patella 1) a fracture from a direct blow the quadriceps tendon being intact and the power of active extension of the knee unimpaired so that operative treatment is not essential and 2) fracture from muscular violence the quadriceps tendon being ruptured and the power of active extension of the knee lost so that operative suture is necessary. It has also been recognised that in operating on a fracture of the patella it is essential to suture the quadriceps expansion. Many surgeons have done no more than this and have not stitched the bone itself. It is but one step further to recognise that the tendon can be stitched even more securely if the bone fragments are first excised.

Rupture of the quadriceps tendon is essentially the same injury whether the injury is at the level of the upper margin the middle or the lower pole of the patella (so-called avulsion of the quadriceps fracture of patella and avulsion of the ligamentum patellæ) and that preservation of the patella is not essential to the successful treatment of this rupture[1-4]. The necessary treatment is to suture the tendon and whether the bone fragments are preserved or excised does not influence this main principle.

The quadriceps tendon is ruptured by a powerful muscle contraction against a stress acting in the opposite direction. The patient stumbles the knee is flexed forcibly by body weight and in the attempt to avoid a fall the movement is resisted by quadriceps contraction. A painful snap is followed by rapid filling of the joint with blood, and it is found that the power of active extension is lost although passive extension is not limited. A gap may be felt between the torn fibres or between the bone fragments indicating the level of rupture.

Rupture of the tendon at four levels will be considered 1) rupture at the upper margin of the patella—the injury known as avulsion of the quadriceps which usually occurs in elderly patients 2) rupture at the level of the patella accompanied by fracture of the patella, occurring at any age but usually in middle life 3) rupture at the lower pole of the patella described as avulsion of the ligamentum patellæ and occurring in young patients 4) avulsion from the tibia including fracture of the tibial tubercle and separation of the epiphysis of the tibial tubercle or Schlatter's sprain which occurs in adolescence.

AVULSION OF THE QUADRICEPS MUSCLE

The pathological features of avulsion of the quadriceps muscle are described on pages 58-59. The injury usually occurs in elderly patients and bilateral avulsion is not uncommon[5]. Loss of active extension of the knee with tenderness at the upper margin of the patella in an elderly patient

Blodgett W. E., and Fairchild, R. D. "Results of Total and Partial Excision of Patella for acute Fracture (twenty cases)." *J. Amer. med. Ass.* 1936, 106, 2121.
Dodd, H. "Fractured Patella treated by excision of the Fragments." *Lancet*, 1930, 2, 130.
Brockman, E. P. "Fracture and Dislocation of the Patella." *Brit. med. J.* 1930, 2, 963.
Murphy, J. J. "Bilateral Fracture of the Patella—one sutured, one excised." *Brit. med. J.*, 1943, 1, 725.
James, A. L. "Bilateral Rupture of Quadriceps Tendon." *Brit. med. J.*, 1939, 2, 1309. (James suggests that there was no previous reference in the literature to bilateral rupture but this is inaccurate.)

are formed Small fragments of bone which remain attached to the dista part of the tendon may be excised in order to facilitate suture It may b possible to stitch the tendon so securely that early active movement are safe, but since the injury occurs in young patients who show littl susceptibility to stiffening of the joint the knee should usually be immobilise in almost full extension for six or eight weeks

FRACTURE OF THE TIBIAL TUBERCLE

SEPARATION OF THE EPIPHYSIS OF THE TIBIAL TUBERCLE

The ligamentum patellæ which is inserted into the tibial tubercle is n more than the central part of the tendon of insertion of the quadricep muscle The tubercle is the apex of a triangular area of insertion spreadin laterally over the tibial tuberosities This apical region takes the firs strain of an extensor injury and with so wide an area of insertion complet avulsion of the tendon is exceptional

Fracture of the tibial tubercle—In the adult where the tubercle is firml fused to the tibia by a broad base avulsion injuries are rare When very stiff knee joint is forcibly manipulated under anæsthesia the tubercl may occasionally be cracked and slightly separated but it will usually b found that the greater part of the quadriceps insertion to the tuberositie is still intact The power of active extension is not reduced and it i unnecessary to immobilise the knee Active flexion exercises may b practised at once and the value of the manipulation need not be los Passive stretching movements must of course be avoided

Osgood s or Schlatter s sprain—The fact that the tibial tubercle take the first strain of extension movement but is supported laterally by th insertion of the tendon into the tibial tuberosities explains the conditio described as Osgood s or Schlatter s disease [1 2] The tubercle is develope as an epiphysis either by extension of the upper epiphysis of the tibia c from a separate centre of ossification and it does not fuse firmly to the tibi until the age of eighteen Before that age the epiphysial line is a wea point in the extensor mechanism of the knee A sudden flexion movemer of the joint against the resistance of the quadriceps muscle tends to avul the epiphysis from the tibia Actual avulsion is prevented by the later insertions of the tendon to the tibial tuberosities but the epiphysial lir of the tubercle is strained The patient complains of tenderness whic is localised accurately to the tubercle The pain is increased by activ extension against resistance If the joint is not protected by immobilisatio repeated strains cause increased separation of the epiphysis and bon thickening develops These are the characteristic features of Schlatter disease It is not a disease It is a simple traumatic conditio comparable to the separation of other epiphyses Recently the Europea champion of figure ice-skating and aspirant to the world title who is age only fifteen years sustained this epiphysial strain All that was needed w rest from full training for two months while the epiphysis regained i attachment—and we still hope that she may become world champion

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Osgood, R. B. "Lesions of the Tibial Tubercle" *Boston med surg J* 1903, 148 114.
Schlatter C. *Bei kl Ch* 1903, 38, 518

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[1] Brooke, R.: "Removal of Patella for Simple Fracture," *Proc. Roy. Soc. Med.*, 1937, 30, [illegible].
[2] Brooke, R.: "Treatment of Fractured Patella by Excision—a Study in Morphology and Function" (*report of thirty cases of primary excision*), *Brit. J. Surg.*, 1937, 24, 733.

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FIG. 1240

FIG 1241

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Fig. 1232

Dangers of wire sutures for fracture of patella

A fracture of the patella was treated many years before by suture with wire which dissolved. One fragment was removed from the back of the joint. The patella was excised

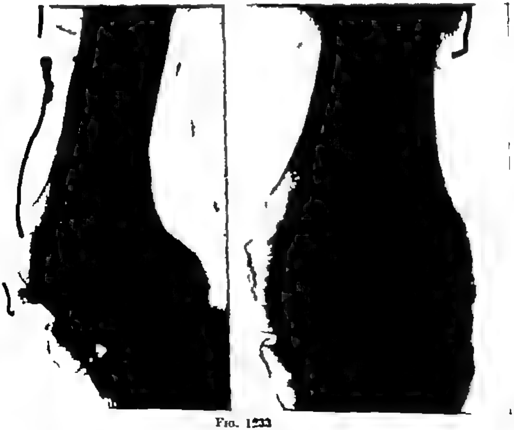

Fig. 1233

Unreliability of wire for suture of fracture of the patella

Un-united fracture of patella with six inches of separation of the fragments. The wire was dissolved by ionisation and broke into many fragments. But the patient made no complaint until, after many years, he developed tabes dorsalis.

are formed. Small fragments of bone which remain attached to the distal part of the tendon may be excised in order to facilitate suture. It may be possible to stitch the tendon so securely that early active movements are safe, but since the injury occurs in young patients who show little susceptibility to stiffening of the joint, the knee should usually be immobilised in almost full extension for six or eight weeks.

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Fracture of the tibial tubercle—In the adult, where the tubercle is firmly fused to the tibia by a broad base, avulsion injuries are rare. When a very stiff knee joint is forcibly manipulated under anæsthesia the tubercle may occasionally be cracked and slightly separated, but it will usually be found that the greater part of the quadriceps insertion to the tuberosities is still intact. The power of active extension is not reduced and it is unnecessary to immobilise the knee. Active flexion exercises may be practised at once and the value of the manipulation need not be lost. Passive stretching movements must of course be avoided.

Osgood's or Schlatter's sprain—The fact that the tibial tubercle takes the first strain of extension movement but is supported laterally by the insertion of the tendon into the tibial tuberosities explains the condition described as Osgood's or Schlatter's "disease".[1,2] The tubercle is developed as an epiphysis either by extension of the upper epiphysis of the tibia or from a separate centre of ossification, and it does not fuse firmly to the tibia until the age of eighteen. Before that age the epiphysial line is a weak point in the extensor mechanism of the knee. A sudden flexion movement of the joint against the resistance of the quadriceps muscle tends to avulse the epiphysis from the tibia. Actual avulsion is prevented by the lateral insertions of the tendon to the tibial tuberosities, but the epiphysial line of the tubercle is strained. The patient complains of tenderness which is localised accurately to the tubercle. The pain is increased by active extension against resistance. If the joint is not protected by immobilisation repeated strains cause increased separation of the epiphysis and bony thickening develops. These are the characteristic features of Schlatter's "disease". It is not a disease. It is a simple traumatic condition comparable to the separation of other epiphyses. Recently the European champion of figure ice-skating and aspirant to the world title, who is aged only fifteen years, sustained this epiphysial strain. All that was needed was rest from full training for two months while the epiphysis regained its attachment—and we still hope that she may become world champion.

It may sometimes be necessary to support the knee in plaster in the

[1] Osgood, R. B. "Lesions of the Tibial Tubercle." Boston med surg J 1903, 148, 114.
[2] Schlatter C. Beitr kl Chir 1903, 38, 513.

establishes the diagnosis. Radiographs show no abnormality until several weeks have gone by and for this reason the diagnosis is sometimes overlooked. If the quadriceps is not stitched back ossification in the hæmatoma between the retracted muscle and the patella gives rise to the condition described as "myositis ossificans of the quadriceps" (Figs 120 122). If the joint is immobilised on a splint the new bone fuses to the patella but if passive movements are permitted the hæmatoma is disseminated and the bone is scattered.

The correct treatment is to make a straight vertical insertion [1] and suture the muscle to its tendon in front and on the sides of the patella by catgut mattress sutures. External splinting is seldom necessary, and active flexion movements may begin within a few days. Weight bearing is resumed after about four weeks. Complete recovery with a full range of movement and freedom from abnormal ossification should be possible within a few months.

Sometimes the avulsion is incomplete and no more than the central fibres of the rectus femoris are torn. The attachments of the vastus lateralis and vastus medialis are intact and full active extension is possible. Operative treatment is then unnecessary. The joint is protected by a back splint for ten or fourteen days and subsequently by a crêpe bandage. Early flexion exercises are advisable in order to prevent stiffness of the joint.

RUPTURE OF THE QUADRICEPS TENDON WITH FRACTURE OF THE PATELLA

When the patella is fractured the quadriceps muscle retracts with the proximal fragment of the bone. The distal fragment is usually tilted with its fractured surface forwards the surface being covered by aponeurotic fibres of the tendon which fall in towards the joint. The rupture of the tendon extends laterally on each side of the patella. The joint is filled with blood and clot. Without operative treatment the muscle and proximal fragment of bone remain retracted the gap fills with scar tissue and repair takes place with lengthening of the tendon and permanent limitation of active extension movement. Operative suture is advisable as soon after injury as the condition of the skin will permit. Suitable preparation of the skin should be continued for not less than twenty four hours and if abrasions wounds or any other source of skin infection exist the operation should be deferred for a few days.

Suture of tendon and of patella [2-4]—The fractured surfaces of the patella are cleared of fibrous tissue and freshened and blood clot is evacuated from the joint. The fragments are accurately apposed and held by towel clips or a special clamp while a suture of strong catgut is passed close to the bone through the muscle above and the ligament below. One or both fragments may be drilled horizontally the suture being passed through the drill hole. Special care must be taken not only to close the gap between the fragments but also to fix them in such accurate apposition that no ridge remains on the articular surface. The quadriceps tendon on each side of the

[1] There is danger in using a U-shaped incision and raising a flap, especially in elderly patients, because the apex of the flap may slough. Straight incisions are nearly always best.
[2] McMahon, C. G. "Operative Treatment Fracture Patella." *Neb. St. med. J.*, 1935, 20, 264.
[3] Campbell, Willis. "Fracture of Patella" (review of end results in a series of one hundred and twenty-seven fractures of patella—suture with wire recommended). *Sth. med. J.*, *Nashville* 1935, 28, 401.
[4] Watson-Jones, R. "Fractures of Extensor Apparatus of Knee." *Canad. med. Ass. J.*, 1931 N.S. 24, 803.

position of full extension for about two months Protection should be continued until relief of pain and tenderness proves that the epiphysis has become reattached to the tibia

This epiphysial separation does not necessarily undergo spontaneous fusion at the age of eighteen when it should normally join with the tibia it may fail to fuse A patient aged forty years complained of pain tenderness and bony thickening in the region of the tibial tubercles of both knee joints and of inability to kneel The symptoms had been present since adolescence Radiographs show evidence of old untreated bilateral Schlatter's sprain (Figs 1245-1246) *Failure to immobilise the joints at the time of the original injury* allowed repeated separation and elevation of the epiphyses throughout the period of active growth with deposition of successive layers of bone Despite this bone formation continued strain prevented fusion of the epiphysial lines and the epiphyses remained as separate ossicles

Fig 1242 Fig 1243 Fig 1244

Three types of avulsion fracture of the upper tibial epiphysis.

joined to the tibia only by fibrous tissue which was susceptible to strain The symptoms were relieved by excision of the fragments of bone and immobilisation of the joints in extension for two months

Complete avulsion of the epiphysis of the tibial tubercle—More violent injury may cause complete avulsion of the tendon of insertion of the quadriceps together with one or more fragments from the epiphyses of the tibial tubercle and head of the tibia The typical injury is that sustained by the boy of fourteen whose radiographs are shown in Figure 1247 He was attempting the high jump at school sports and landed with his body weight slightly behind his feet so that he fell backwards into the sitting position The knee joint was forcibly flexed against the resistance of the strongly contracting quadriceps muscle and the tendon of insertion was avulsed

The injury is most common before the age of eighteen when the epiphyses of the tubercle and head of the tibia fuse to the shaft of the bone Three types of injury may be differentiated 1) A small fragment representing part of the tibial tubercle may be avulsed and retracted upwards (Fig 1242) This part of the tubercle sometimes develops as a separate centre of ossification which fuses to the ossific centre of the upper tibial epiphysis at the age of sixteen Before that age the cartilage between the two centres is a weak junction susceptible to separation *The small fragment cannot be replaced accurately by manipulation and operative*

FIG. 1245

FIG. 1246

Bilateral Schlatter's sprain, the result of strain of the epiphyses during adolescence, causing recurrent symptoms in an adult because the epiphyses never united by bone.

FIG. 1[illegible]

FIG. 1248

Avulsion of tibial tubercle epiphysis before and after operative reduction.

Fig. 125

Fig. 138

Fracture of the lateral tuberosity of the tibia without comminution or separation of a marginal fragment, before and after manipulative reduction.

treatment is necessary It may be held in its normal position by suture of the overlying soft tissues or by passing a catgut suture through drill holes in the bone Screws nails or pegs are unnecessary The limb is immobilised in plaster for eight or ten weeks and movements are then regained by active exercise 2) When there is no separate centre of ossification for the tubercle, or if there has been such a centre when *it is fused to that of the upper tibial epiphysis*, the quadriceps tendon is more securely fixed to a broad area of bone Instead of a small fragment being avulsed the whole lip formed by the front of the upper tibial epiphysis is hinged upwards without being completely fractured at its base (Figs 1244-1246) The fragment can usually be replaced by manipulation and *operative reduction is unnecessary* 3) Sometimes the injury is of such severity that even this broad lip of bone is fractured at its base the line of fracture passing upwards and backwards into the joint surface The large piece of bone which is displaced can sometimes be reduced accurately by manipulation but if manipulative reduction fails or if the *fragment is comminuted as is the case shown in Figures 1247 1248 operative* suture with catgut may be indicated It is still unnecessary to use the fixation of screws or pegs [1 2]

COMMINUTED FRACTURE OF THE PATELLA FROM DIRECT VIOLENCE

The fractures of the patella described on pages 778-784 are incidental to a primary rupture of the quadriceps tendon The patella may also be injured by a direct blow crushing the bone against the femoral condyles so that a comminuted stellate fracture is produced Since the quadriceps tendon is not ruptured there may still be a full range of active extension movement and operative treatment is often unnecessary If displacement of the fragments is minimal and the articular surface is smooth there is need only to protect the joint for two or three weeks by a posterior plaster slab and immediate weight bearing may be permitted Flexion movements are *allowed after* a few weeks If the fragments are displaced manipulative reduction is sometimes advised Blood and synovial fluid are aspirated from the joint the patella is firmly *compressed* against the femoral condyles with the object of restoring a smooth articular surface and a complete plaster cast is applied with sponge *rubber* over the patella to continue the elastic support *However in the specimen shown in* Figure 1240 it is obvious that damage to the articular cartilage may be of such severity that a perfect joint surface cannot possibly be restored by manipulation All comminuted

FIG 1249

Comminuted fracture of patella The quadriceps expansion has not been ruptured but the articular surface is severely damaged. Excision is advisable in such cases.

[1] Clark H Osmond "Fracture of Tibial Tubercle" *Proc Roy Soc Med.* (Section Orthopaedics), 1934, 28, 1013
[2] Fairbank, H A T "Avulsion of Tibial Tubercle" *Proc Roy Soc Med.* (Section Orthopaedics), 1934, 28, 1014

FIG. 1259

Fracture of the lateral tuberosity of tibia. The medial and anterior crucial ligaments are torn. It is obvious how the tibial tuberosity has been split and crushed by impact of the margin of the femoral condyle.

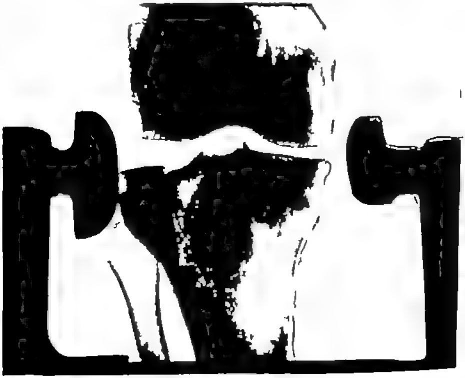


FIG. 1260

fractures of the patella with more than minimal displacement and in which the joint surface is seriously damaged, are best treated by excision of the bone Since the quadriceps tendon is intact the operation is easy and early active movements may be practised with safety

Excision for old mal united fracture of patella—A window-cleaner sustained a comminuted fracture of the patella which united with marked irregularity of the articular surface Physiotherapy electrotherapy and manipulative treatment continued for nearly two years failed to relieve the pain or to increase the range of flexion movement beyond 80 degrees and the patient was totally incapacitated Under anæsthesia the patella was excised the joint fully flexed and the tendon repaired (Fig 1250) After three months of active exercise the range of movement of the joint was normal pain was relieved and the man went back to work.

Marginal fracture of the patella—A direct blow may chip a large fragment of bone from one of the angles of the patella [1] The bone is *not crushed* the fragment is not displaced and the articular surface is smooth Operation is unnecessary and immobilisation is not indicated The fracture is to be distinguished from congenital bipartite patella, in which a supernumerary bone develops at the upper outer angle from a second centre of ossification This anomaly may be bilateral and seldom causes disability

Chip fracture of articular surfaces—Contusion of the patella against the femoral condyle may bruise the articular cartilage and cause a localised area of osteochondritis dissecans [2] Many cases have been described of detachment of a fragment from the inferior medial angle of the articular surface of the patella by impact of the bone against the lateral femoral condyle the loose fragment in each case being removed from the lateral pouch of the knee [4] In many injured knee joints where there has been forcible impact of the patella against the femoral condyles it will be found at operation that apart from detached fragments of bone there are quite large detached fragments of articular cartilage which of course are not disclosed in radiographs Very often chip fractures involving the articular surface of the bone were sustained during momentary lateral dislocation of the patella and of course they occur still more frequently in recurrent lateral dislocations where frequent displacement of the patella over the lateral femoral condyle gives rise to so many more opportunities for fracture

FIG 1250

Patella excised from the knee joint of a window cleaner who sustained a comminuted stellate fracture. Mal-union, causing irregularity of the articular surfaces gave rise to persistent pain and limitation of movement.

Mera, A B and Teramo, M "Vertical Fractures of Patella" (with full bibliography) *Palest ico (Sezione Chirurgica)*, 1938 45, 63.
Ruggles George "Bilateral Bipartite Patella" *Brit. J Surg* 1934, 22, 553
Rombold, C "Osteochondritis Dissecans of Patella." *J Bone Joint S rg* 1936 18, 230.
Meekison, D M "Undescribed fracture of Patella" *Brit J Surg* 1937 25, 64.

the tibial tuberosity and the neck of the fibula The fracture enters the joint in the non articular region of the tibial spine The articular surfaces themselves are uninjured and there is therefore little danger of arthritis Damage to the ligaments is less serious than in the second type of injury and the cruciate ligaments may escape altogether The displacement can usually be corrected by traction and manipulation and in recent fractures operative reduction is unnecessary The prognosis is excellent If the valgus deformity is corrected the levels of the tuberosities equalised and the tone of the thigh muscles maintained an almost perfect result may be assured

Comminuted fracture of tuberosity—In the second type of fracture a large fragment is detached from the lateral margin of the tuberosity and it is usually tilted and displaced laterally Radiographs of imperfect quality may suggest that this is the only bone injury and even lead to the erroneous assumption that it is caused by a glancing blow to the side of the tuberosity Actually the fragment is split off by the impact of the margin of the femoral condyle to the articular surface and good radiographs show evidence of the associated injury to the central part of the tuberosity which is usually comminuted The ligaments are often ruptured The lateral semilunar cartilage may be torn and driven into the head of the tibia The articular surface is seriously damaged Wedging of fragments at the base of the marginal fragment may obstruct reduction Many fragments are cut off from their blood supply Avascular necrosis may cause degeneration of the overlying cartilage The dangers of persistent instability and of degenerative arthritis are obvious Nevertheless there is almost never any justification for immediate arthrodesis Although the prognosis should be guarded accurate reduction complete immobilisation and muscle development usually succeed in restoring a useful and serviceable joint

Treatment of depressed fractures of the lateral tibial tuberosity[1 2]—Figure 1207 shows a typical depressed fracture of the intact lateral tibial tuberosity The fracture enters the joint in the region of the tibial spine The articular surface is smooth and uninjured the tuberosity is impacted on the outer side and posteriorly—causing genu valgum and limitation of extension—and there is a comminuted impacted fracture of the neck of the fibula

Manipulative reduction—Strong traction should be applied to the fully extended knee by which to correct the impacted valgus position the surgeon moulding the position of the fragments after which a padded plaster cast is applied from the toes to the groin Quadriceps exercise should begin at once the muscle being exercised regularly by rhythmic contraction and relaxation Within a few days the patient lifts the limb against the resistance of gravity After about eight weeks the plaster cast may be removed a crêpe bandage being used to prevent swelling weight-bearing being resumed and active flexion exercises practised

Treatment of comminuted fractures of the tuberosity—Reduction of the comminuted type of fracture is much more difficult Many fragments of bone and cartilage have been driven into the head of the tibia They cannot be elevated by manipulation or by spikes introduced subcutaneously Operative reduction may be possible but levering up impacted fragments and fitting them together like the pieces of a jig-saw puzzle demands the

Leriche R., and Jung, A. "Ostéosynthèse dans Fractures du Plateau Tibial." *Rev Chir Paris* 1930 **68**, 3 1
Clark H Osmond. *Proc Roy Soc Med* (Section of Orthopædics) 1934 **28**, 1010
Fairbank, H A T *Proc Roy Soc Med* (Section of Orthopædics) 1934 **28**, 1010

LATERAL DISLOCATION OF THE PATELLA

The mobility of the patella varies in normal individuals If the capsule of the joint is lax and the lateral femoral condyle is poorly developed so that the patellar groove is shallow the patella may be so mobile that relatively slight pressure is sufficient to displace it over the margin of the femoral condyle An injury sustained while the muscles of the thigh are relaxed may completely dislocate the bone [1] The tibia is forcibly abducted and laterally rotated or the patella is struck on its medial side by a glancing blow The capsule is stretched or torn, the patella rotates through 90 degrees and its articular surface lies in contact with the outer side of the lateral femoral condyle The dislocation is often reduced spontaneously as the joint is extended or it is replaced by the manipulation of onlookers When the surgeon examines the knee the only clinical signs remaining may be those of traumatic synovitis and tenderness over the patellar margin at the attachment of the vastus medialis It may be difficult therefore to differentiate dislocation of the patella from displacement of a semilunar cartilage The history must be elicited carefully the site of greatest tenderness determined and the degree of lateral mobility of the patella estimated The joint should be immobilised on a back splint or in plaster for two months, wasting of the quadriceps being prevented by regular active exercise

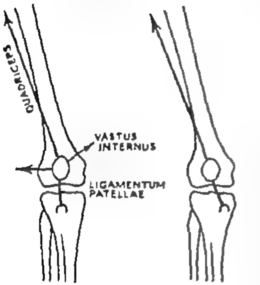


FIG 1251

The relative axes of the quadriceps and the patellar ligament encourage lateral displacement of the patella, normally prevented by the vastus medialis. Transplantation of the tibial tubercle corrects the tendency

Recurrent dislocation of the patella—The relation between the axes of the quadriceps muscle and the ligamentum patellæ predisposes to outward displacement of the patella The muscle passes downwards and inwards but the ligament lies vertically and the patella is situated at the angle between the two (Fig 1251) When the muscle contracts it tends to form a straight line between its origin and insertion so that the angle is obliterated and the patella is displaced outwards This tendency is normally corrected by the lowermost fibres of the vastus internus which lie in an almost horizontal axis The vastus internus contracts simultaneously with the other muscles of the quadriceps group so that it pulls the patella inwards at the moment that it would otherwise displace over the lateral femoral condyle

Non-operative treatment—Wasting and hypotonicity of the vastus medialis after dislocation of the patella may therefore cause recurrent dislocation The protective function of this muscle is lost It follows that recurrent dislocation of the patella which is not of congenital origin and which

[1] [illegible] "Traumatic Lateral Dislocation of Patella," [illegible] 1912, 83, 431.

Fig. 1201

Comminuted fracture of the lateral tuberosity of tibia, with rupture of lateral and cruciate ligaments, and such severe damage to the joint surface that some fragments are upside down. In such a case operative reduction is essential.

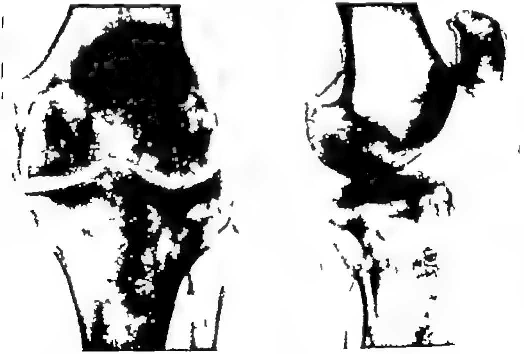


Fig. 1202

Despite osteoarthritis from avascular necrosis of loose fragments, muscle control is so good that symptoms are negligible and after ten years the patient still works as a labourer.

develops for the first time in adolescent or adult life does not necessarily require operative treatment Many cases have been cured by the simple measure of redeveloping the tone of the thigh muscles Quadriceps exercise should be practised for five minutes hourly throughout the day together with faradic stimulation of the vastus medialis for fifteen or thirty minutes each day

Operative treatment[1-6]—If muscle redevelopment fails to prevent recurrence of the dislocation operation is indicated The angle between the quadriceps muscle and the ligamentum patellæ should be straightened by displacing the tubercle of the tibia medially (Fig 1251) Since the ligamentum patellæ and quadriceps muscle are then in the same straight line recurrence of the dislocation is prevented The tubercle is buried under the cortex of the tibia in the region of the insertion of the semitendinosus and gracilis tendons and the capsule of the knee joint is plicated on the medial side The limb should be immobilised in plaster for six weeks quadriceps exercise being practised throughout that time

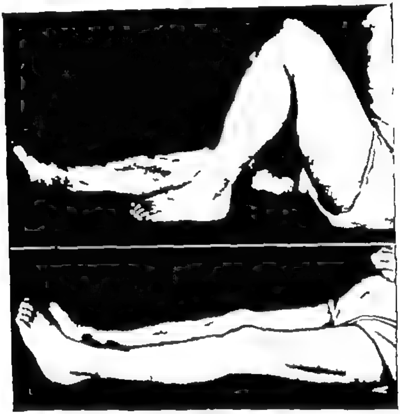
Recurrent dislocation of the patella from knock knee deformity[7] If a patient has severe genu valgum the angle between the ligament and muscle is so increased that this in itself may cause recurrent dislocation but of course we should recognise that preventive orthopædic treatment has advanced so far in the last few decades that genu valgum sufficient to cause recurrent dislocation of the patella is now virtually non-existent

Fig. 1252
Congenital recurrent lateral dislocation of the right patella in a child.

Congenital recurrent dislocation of the patella—In the congenital type of recurrent displacement of the patella there is no history of injury or of acute dislocation followed by recurrent dislocation For as long as the patient could remember the patella had displaced over the lateral condyle every time the joint was flexed (Fig 1252) The capsule on the medial side is very lax and the lateral femoral

Goldthwait, J E "Recurrent Dislocation of Patella." *Boston med surg J.*, 1904 150, 169 (In Goldthwait's operation, only the outer half of the ligamentum patellæ and tibial tubercle is displaced to the inner side)
Goldthwait, J E "Permanent Dislocation of the Patella. *A* [illegible] *Surg* 1899 29, 62.
Gallie W E, and *Le Mesurier A B.* "*Habitual Dislocation of Patella.*" *J Bone Joint Surg* 1924 [illegible] 575 (fixation by fascia lata suture to femoral condyle).
Bowtier, R "New Operation for Slipping Patella." *J Amer med Ass* 1924 82, 1961 *New Engl. J Med.*, 1933, 208, [illegible] (fixation of patella to inner tibia by fascia lata suture).
Ober F R "Recurrent Dislocation Patella." *J Bone Joint Surg* 1935, 17 774 (fixation patella to tibia by the ilio-tibial band).
Hauser E. D W "Total Tendon Transplant for Slipping Patella " (*full bibliography and review of literature*) *Surg Gyn Obstet.*, 1938 66, 199
Jones Robert, and Lovett, R. W "Orthopedic Surgery " *Oxford Med Pub* 2nd ed., 1929 [illegible]

highest standard of operative skill and is usually quite impossible after about fourteen days There is a still more serious objection to operative reduction The loose fragments have an impaired blood supply and at the conclusion of an operative reduction they have no blood supply at all Avascular necrosis with replacement of the articular cartilage by fibro-cartilage or fibrous tissue is inevitable Elevating necrotic cartilage so that it lies at the joint level where it will articulate with the femur is of questionable value to the joint On the other hand if soft tissues have not



FIGS. 1263-1264

Same case as in Figures 1261 1262 ten years after operative reduction. Movement is almost normal, muscle control is excellent and the ligaments have united so that stability is normal.

been dissected from the bone in the course of operative reduction the main marginal fragment has a normal blood supply

Manipulative reduction—It seems probable therefore that the best treatment is often to replace the marginal fragment with its living articular cartilage but to leave avascular fragments with necrotic cartilage buried in the head of the tibia The central crater from which these fragments are displaced fills with fibrous scar tissue and the remnants of the lateral semilunar cartilage It is surrounded by living articular cartilage which later bears weight and sustains the function of the joint Traction is applied and the valgus deformity is corrected The bone is compressed laterally and a special clamp may be used for this (Figs 1259-1260)

Operative reduction—Sometimes the tuberosity is so comminuted that manipulative reduction is obviously impossible Figure 1261 illustrates such a case The marginal fragment is relatively small and the whole of the

LATERAL DISLOCATION OF THE PATELLA

The mobility of the patella varies in normal individuals. If the capsule of the joint is lax, and the lateral femoral condyle is poorly developed so that the patellar groove is shallow, the patella may be so mobile that relatively slight pressure is sufficient to displace it over the margin of the femoral condyle. An injury sustained while the muscles of the thigh are relaxed may completely dislocate the bone.[1] The tibia is forcibly abducted and laterally rotated, or the patella is struck on its medial side by a glancing blow. The capsule is stretched or torn, the patella rotates through 90 degrees and its articular surface lies in contact with the outer side of the lateral femoral condyle. The dislocation is often *reduced spontaneously as the joint is* extended or it is replaced by the manipulation of onlookers. When the surgeon examines the knee the only clinical signs remaining may be those of traumatic synovitis and tenderness over the patellar margin at the attachment of the vastus medialis. It may be difficult therefore to differentiate dislocation of the patella from displacement of a semilunar cartilage. The history must be elicited carefully, the site of greatest tenderness determined and the degree of lateral mobility of the patella estimated. The joint should be immobilised on a back splint or in plaster for two months, wasting of the quadriceps being prevented by regular active exercise.

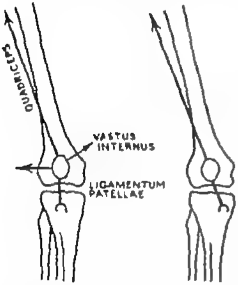


FIG. 1231

The relative axes of the quadriceps and the patellar ligament encourage lateral displacement of the patella, normally prevented by the vastus medialis. Transplantation of the tibial tubercle corrects the tendency

Recurrent dislocation of the patella—The relation between the axes of the quadriceps muscle and the ligamentum patellæ predisposes to outward displacement of the patella. The muscle passes downwards and inwards but the ligament lies vertically and the patella is situated at the angle between the two (Fig. 1231). When the muscle contracts it tends to form a straight line between its origin and insertion, so that the angle is obliterated and the patella is displaced outwards. This tendency is normally corrected by the lowermost fibres of the vastus internus which lie in an almost horizontal axis. The vastus internus contracts simultaneously with the other muscles of the quadriceps group so that it pulls the patella inwards at the moment that it would otherwise displace over the lateral femoral condyle.

Non-operative treatment—Wasting and hypotonicity of the vastus medialis after dislocation of the patella may therefore cause recurrent dislocation. The protective function of this muscle is lost. It follows that recurrent dislocation of the patella which is not of congenital origin and which

[1] [illegible] "Traumatic Lateral Dislocation of Patella," J. ... Surg., 1932, [illegible]

rest of the tuberosity has been ploughed and furrowed Some fragments lie upside down wedged between the front of the femur and tibia and others are forced into the head of the tibia

The joint is opened on the lateral side and the fragments are fitted together in their original positions There is no need to remove the meniscus—there is no evidence that in these injuries it ever gives rise to internal derangement Sometimes the displaced lateral marginal fragment should be secured by the transfixion of a screw or by an encircling wire The external support of a plaster is then maintained for three months quadriceps drill being practised for five minutes hourly throughout the day The successful result shown in Figures 1262 1264 despite avascular necrosis and degenerative arthritis was undoubtedly the result of maintenance of such perfect muscle control that the joint was guarded from all twists and strains

Arthroplasty and arthrodesis—Accurate replacement of the fragments by operation is possible only within a few weeks of injury After that the alternatives of arthroplasty or arthrodesis may have to be considered Let it first be said that surprisingly good function is often regained from simple conservative treatment A trial should always be given to securing the best possible position by simple manipulative procedures No matter how grotesque the radiographic appearance may be the functional results are often much better than might be expected If nevertheless there is painful stiffness and instability the alternatives of arthrodesis or arthroplasty must be considered For elderly patients who do not want to pursue an energetic life but only to sit in comfort arthroplasty by the Campbell technique is perhaps the best solution but for younger and more vigorous patients it is better to do an arthrodesis removing the remnants of articular cartilage packing the space with cancellous chip grafts from the ilium and adding the internal fixation of a three flanged nail driven between the two bones

Summary of the treatment of fractures of the lateral tibial tuberosity—There is probably no more difficult problem than that of the treatment of split and crushed fractures of the lateral tuberosity of the tibia into which *the margin of the femoral condyle has been driven* But the concluding note must be one of optimism Despite the gravity of the injury to bone and to articular surfaces astonishingly good function is regained if the torn ligaments are protected during the first two or three months while at the same time muscle control is preserved by regular active exercises—practised frequently throughout every day with almost a religious fervour There is of course sometimes wisdom in pursuing operative treatment with internal fixation—but the conservative methods of manipulative reduction protection of torn ligaments and faithful maintenance of muscle control may give equally good results I cannot express too forcefully my disagreement with Palmer of Sweden who wrote recently of these fractures conservative treatment is rather an expression of therapeutic nihilism in which the end results are left to chance Surely there has seldom been greater misrepresentation of the principles of fracture treatment

[illegible] tt P M Pherson A Pike M Fr [illegible] of Tibia int Knee Joint New Engl J Med 1931 204, [illegible]
Eliason, E. L. & Ebeling W Treatment Fractures Tibia in [illegible] knee " Surg Gyn Obstet 1933, 57 65
Cotton, F J and Berg R Fender Fractures of Tibia at Knee " New Engl. J Med 19[illegible] 201, [illegible]
Cotton, F J Fender Fractures, Surg Gyn Obstet 1936 62, 4[illegible]
Cubbins W R Conley A H and Seiffert G S [illegible] Surg Gyn Obstet. 19[illegible] 48 106.
Hohlen, O [illegible] Ch 1932 [illegible], 344
Campbell, Willis Operative Orthopedics " London Henry K[illegible]
Palmer I Fractures of the Upper End of the Tibia J Bone [illegible] 1 [illegible], 1[illegible]

develops for the first time in adolescent or adult life, does not necessarily require operative treatment Many cases have been cured by the simple measure of redeveloping the tone of the thigh muscles Quadriceps exercise should be practised for five minutes hourly throughout the day, together with faradic stimulation of the vastus medialis for fifteen or thirty minutes each day

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FIG 1252

Congenital recurrent lateral dislocation of the right patella in a child.

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Gallie W E, and Le Mesurier A B "Habitual Dislocation of Patella." *J Bone Joint Surg* 1924 6 575 (fixation by fascia lata suture to femoral condyle).
Soutter, R "New Operation for Slipping Patella." *J Amer med Ass*, 1924 82, 1261 *New Engl J Med*, 1933 209 46 (fixation of patella to inner tibia by fascia lata suture).
Ober F R "Recurrent Dislocation Patella." *J Bone Joint Surg* 1935 17 774 (fixation patella to tibia by the ilio-tibial band).
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Jones Robert, and Lovett, R W "*Orthopedic Surgery*" *Oxford Med Pub* 2nd ed., 1929 32.

CHAPTER XXVII

INJURIES OF THE LEG

The difficulties that may arise in the treatment of fractures of the shafts of the leg bones include 1) a high incidence of open and infected fractures because the tibia lies superficially just beneath the skin 2) a tendency to redisplacement of the fragments when swelling subsides particularly in oblique and spiral fractures 3) serious disability if the alignment or rotational position of the fragments is imperfect because the knee and ankle joints normally move in the same parallel axis 4) conspicuous disfigurement if apposition of the fragments is imperfect because the tibia lies subcutaneously 5) frequency of slow union because there is often a poor blood supply of the distal fragment 6) a still greater frequency of slow union if continuous traction is employed especially if a heavy weight is used and the fragments are distracted 7) sometimes non union if slow union is not recognised and immobilisation is not suitably prolonged 8) a tendency to recurrent œdema of the foot and leg after removal of plaster and a tendency to rigid clawing of the toes if early exercise is not practised

FRACTURE OF SHAFTS OF THE LEG BONES WITHOUT DISPLACEMENT

Isolated fractures of the shaft of the fibula may be sustained from direct violence they cause no functional incapacity The shaft of this bone serves only for the attachment of muscles and ligaments and it bears no weight so that immobilisation of fractures is unnecessary and the patient may be allowed to walk with the protection of a crêpe bandage Some precaution is needed to be sure that the fracture is in fact an isolated injury because the shaft of the tibia may be fractured at a very different level Fractures of the neck and upper shaft of the fibula are sometimes associated with ruptures of the medial and cruciate ligaments of the knee joint fractures of the lower shaft of the fibula are almost invariably part of fracture-dislocations of the ankle joint and even fractures of the upper third of the shaft of the fibula may be associated with dislocations of the ankle joint (see Figures 251 252)

Greenstick and subperiosteal crack fractures of the shaft of the tibia are often sustained by children and a similar type of fracture may be seen in adults There is no overriding or loss of apposition of the fragments but only angulation which is easily corrected by gentle moulding The limb should be hung over the end of a table with the knee flexed to the right angle and the leg in the line of gravity A lightly padded plaster is then applied from the toes to the tibial tubercle When the plaster is hard it is

condyle is underdeveloped It has even been suggested that as well as transplanting the tibial tubercle and plicating the capsule the lateral condyle should be elevated by a bone-grafting operation—but this is not advised[1,2] Sometimes the capsule is so contracted on the lateral side that the patella cannot be replaced in its normal position and it lies habitually *on the outer side of the femoral condyle* A plastic operation on the capsule of the joint as described by Mouchet and Durand[3] may then be necessary

Vertical dislocation of the patella with interlocked osteophytes—An old gentleman aged sixty-seven years sustained a Colles's fracture which was reduced under gas anæsthesia with a strap applied over his knees to

FIG. 1253

FIG. 1254

Vertical subluxation of the patella in which an osteophyte at its lower margin was locked over an osteophyte from the femoral condyle. It was replaced by manipulation—but with detachment of an osteophyte forming a loose body which so far has given no trouble

minimise the effects of his struggling—and that in itself proves that this case was treated several years ago because nowadays patients do not struggle under anæsthesia When the manipulation of the wrist was complete and the plaster had been applied the patient was asked to get up but protested that he could not—his knee joint was locked The pressure of the strap had pushed the patella upwards and osteophytes at the lower pole of the patella had locked over osteophytes at the upper margin of the femoral condyles so that the joint was in fact completely locked Replacement proved so difficult that the patient had to be anæsthetised once more before the patella could be reduced from its vertically dislocated position (Figs 1253 1254)

[1] Albee F H "Bone Graft Wedge for Habitual Dislocation of Patella. *Med Rec* N Y, 1915, 88, 21.
[2] Albee F H "Orthopedic and Reconstruction Surgery" Philadelphia W. B. Saunders Company 1919
[3] Mouchet, Albert, and Durand, J "Operative Treatment of Complete and Irreducible Congenital Dislocation of the Patella" *J Chir Paris* 1921 18, 225

extended to the groin with the knee in a position slightly short of full extension If post reduction radiographs show that alignment is not perfect the angulation should be corrected by wedging the plaster (p 171) After eight or ten weeks the degree of union may be tested clinically if it is not sound immobilisation in a full length above knee plaster cast should be continued for a further period

FRACTURES OF THE SHAFTS OF THE LEG BONES WITH DISPLACEMENT

It is sometimes difficult to reduce and immobilise fractures of the shafts of the leg bones when there is overriding and complete loss of apposition of the fragments of a horizontal fracture or sliding of the fragments of an oblique or spiral fracture Simple manual reduction may be unsuccessful. Moreover if the fracture line is oblique and swelling is severe redisplacement often occurs despite the application of a well fitting plaster

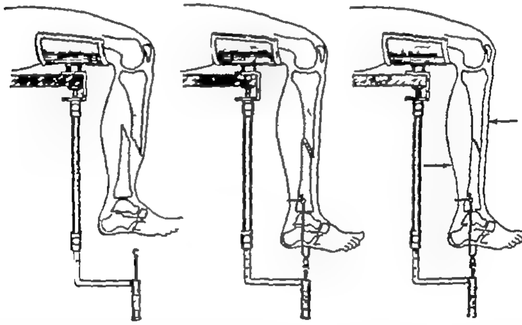


Fig 1205

Tibia traction apparatus with a thigh support clamped to any table to which is fixed an L-shaped traction bar with coarse and fine adjustment Length and alignment is secured by the apparatus while the limb hangs in the line of gravity and apposition is maintained by the pressure of the operator s hands. (*Watson-Jones "J Bone Joint Surg"* 1932, 14 601.)

TREATMENT BY MANIPULATIVE REDUCTION

It is usually possible to reduce a displaced fracture of the shaft of the tibia by simple manipulation and to maintain the reduction by applying a plaster-cast while the limb hangs vertically over the end of a table but the use of a tibia traction apparatus is a great help Figure 1205 shows the one that I have devised and used While the plaster is setting the rotational position of the fractured limb can be controlled by the operator s knees holding the patient s foot the lateral displacement of the fragments being controlled by the operator s two hands (Fig 1206)

Interarticular dislocation of the patella *has sometimes* occurred as a complication of avulsion of the quadriceps muscle when the joint was forcibly flexed and the bone and muscle were torn apart [1] The upper margin of the patella, being freed from all soft tissue attachments engages between the articular surfaces of the femur and tibia—and when the joint is extended the patella remains locked in front of the knee, being rotated round its transverse axis through 90 degrees so that the lower pole points forwards and the upper pole backwards Replacement of the bone with operative suture of the muscle is needed

Intercondylar dislocation of the patella—Another type of displacement of the patella in which it was rotated through 90 degrees round its vertical axis was described on page 746 (Figs 1106-1107) It was driven back, edgewise between the two femoral condyles

FRACTURE OF THE LATERAL TUBEROSITY OF THE TIBIA

A blow on the lateral side of the extended knee forces the joint into the abducted position tears the medial ligament and may sometimes stretch the cruciate ligaments A more severe injury such as the impact of a motor vehicle or the dropping of a heavy weight on the outer side of the limb causes still greater valgus deformity and in addition to rupture of the medial and cruciate ligaments the lateral tuberosity of the tibia may be fractured [2-4] Sometimes the fracture occurs without rupture of the ligaments, but usually a severe valgus strain first tears the ligaments of the joint and then causes depression splitting or comminution of the lateral tuberosity by the impact of the femoral condyle against it Treatment of the soft tissue injury is often no less important than treatment of the fracture

The fate of the joint depends first upon its muscle control If it is not protected by powerful and rapidly contracting muscles the twists and strains of weight-bearing stretch the weak ligaments damage the joint and increase the tendency to arthritis The disability is not relieved by the use of a knee cage On the other hand, if the tone and volume of the muscles of the thigh are maintained by active quadriceps exercises begun the day after injury the joint is guarded. Slight ligamentous instability is then relatively unimportant The joint is controlled by its muscles it is protected from weight bearing strains and arthritis is then seldom progressive

The three essentials of treatment are therefore 1) to correct the displacement and depression of the tuberosity restoring the smoothest possible joint surface 2) to immobilise the limb in plaster long enough for union of the fracture and for repair of the injured ligaments 3) to prevent wasting of the quadriceps muscle by active non weight-bearing exercise begun immediately and continued throughout the period of immobilisation No matter what the type of fracture and no matter whether it is reduced by manipulation or by operation the secret of success is the tone of the muscles of the thigh Quadriceps drill should begin the day after injury and be repeated for five minutes hourly throughout the day It must continue

[1] Jones, J P "Interarticular Dislocation of Patella" (with bibliography of the fourteen published cases by Ass, Paterson Brown, Newman, Rutherford, Perkins Scott and Simmons). *Brit. J Surg* 1928, 16, 336.
[2] Lee H. G "Fractures Tuberosity Tibia." *New Engl J Med.*, 1931, 204 582.
[3] Lowe II. S "Fractures Tibia involving Knee" *Ann. Surg.*, 1920, 89, 560.
[4] Sever J W *New Engl. J Med* 1931, 204, 734

Insertion of traction pin—A traction pin is driven through the tibia one inch above the ankle joint Transfixion of the tibia is more satisfactory than transfixion of the calcaneum especially if the pin is to be left in the bone Low grade serous infection of a calcaneal pin track often causes chronic osteomyelitis persistent sinus formation and stiffness of the subtalar joint A pin passed through soft tissues immediately above the calcaneum is not free from the danger of septic arthritis of the ankle joint and it may cut right through the tendo calcaneus The safest position even in infected fractures of the leg bones is the tibia one inch above the ankle joint

Reduction of the fracture—The technique is the same whether the injury is a closed fracture an open fracture after excision of the wound or an infected fracture after drainage of the wound A stirrup is fitted to the pin the thigh is supported on the sorbo covered rest the limb is lengthened by the coarse adjustment of the apparatus and if further traction is needed it is secured by easy rotatory movements of the fine adjustment handle Traction is increased until the limb is taut and the operator feels the crepitus of fragments in apposition This indicates that overriding has been corrected The traction is such that angulation is also corrected If the axis of the pin is correct there can be no rotational displacement and the toe and patella point in the same direction The fragments are then locked against each other by the firm lateral pressure of the operator s two hands This is an essential step without which accurate reduction cannot be expected. Strong lateral pressure is needed. Radiographs in at least two planes are then taken and if the reduction is satisfactory a plaster is applied

Fig 1966

Tibia traction apparatus showing the operator s grip while the plaster is setting.

Application of plaster—A plaster slab is guided through the stirrup and applied over a thin layer of wool from the toes to the upper calf Special care should be taken by using wool padding or felt to prevent undue pressure over the malleoli the back of the heel and the neck of the fibula If several hours have already elapsed since the injury was sustained no other padding is needed but if the limb has not yet begun to swell it is advisable to use a double strip of thin wool bandage over the foot and leg before the encircling turns of plaster bandage are applied The wool helps to accommodate swelling and if after a few hours impairment of circulation of the toes indicates that the plaster is too tight it can easily be cut longitudinally over the front of the foot and leg and through the wool bandage without injury to the skin The plaster is then completed and while it is setting

until the plaster is removed Within three months of injury the muscles should be as strong as those of the normal limb They should be so powerful that the fitting of a knee cage is obviously unnecessary

Two types of fracture of lateral tibial tuberosity—Many groups of fracture of the lateral tuberosity have been described[1 2] but only one subdivision is of clinical importance Of the two types each has a distinctive etiology radiographic appearance method of treatment and prognosis 1) depressed fracture without comminution and without injury to the articular surface this fracture may be reduced by manipulation the injury to ligaments is minor and the prognosis is excellent 2) comminuted fracture with

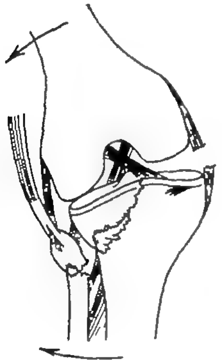


FIG 1235

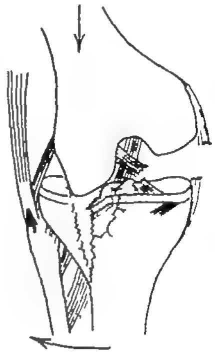


FIG 1236

Mechanism of injury in the two types of fracture of the lateral tuberosity of the tibia. In the first type the tuberosity is depressed by the surface of the lateral femoral condyle (Fig 1235) In the second type the tuberosity is split by the margin of the femoral condyle and a marginal fragment is displaced (Fig 1236) In both there may be ligamentous damage to the medial ligament and sometimes to the cruciate ligaments.

separation of a marginal fragment and severe injury to the articular surface this fracture is difficult to reduce either by manipulation or operation and there may be rupture of the medial ligament or even of the cruciate ligaments there is danger of arthritis and the prognosis is doubtful (Figs 1235-1236)

Depressed fracture of the intact tibial tuberosity—Abduction displacement of the joint may crush the lateral tuberosity against the femoral condyle and the whole tuberosity is then depressed and impacted (Figs 1237 1238). The fracture may be regarded as one part of an oblique line of injury through the medial ligament the inner half of the knee joint the base of

[1] Clarke H Osmond. "Fracture of Tibia involving Knee Joint." *Proc Roy Soc Med*, 1934 28, 1037
[2] Hamm, T T "Fracture of Tibia involving Knee." *Proc Roy Soc Med* 1934 28, 1047

FIG. 1267

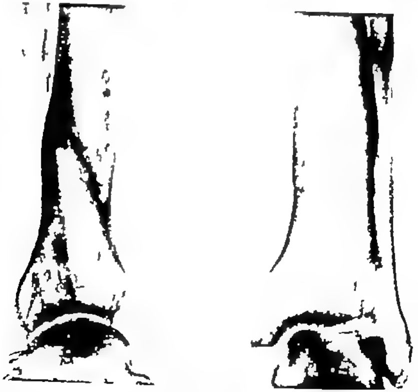


FIG. 1268

Oblique fractures of the shafts of the leg bones before and after reduction by the traction apparatus shown in Figure 1266, with simple immobilisation in plaster thereafter. There was no continuous traction and yet, by simple conservative treatment a perfect result was secured.

strong lateral pressure is again maintained with the palms of the operator's hands. As soon as the plaster is hard, traction is released and the knee is straightened to a position of 30 degrees short of full extension. The plaster is then extended to the upper thigh and moulded round the knee in order to prevent rotational displacement.

Continuous traction after reduction—Fractures of the tibia should be reduced accurately and be immobilised in a simple plaster cast. In former years it was customary to maintain continuous traction from a skeletal pin in the lower shaft of the tibia or perhaps in the calcaneum, especially when it was thought that the fracture was of an unstable type which might redisplace (Fig. 1269). But we now know that such skeletal traction always delays union, and if there is actual distraction of the fragments the rate of

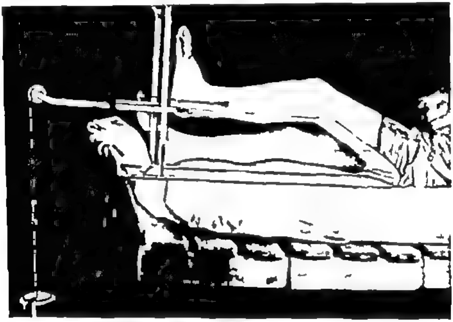


Fig. 1269

Formerly unstable fractures of the shaft of the tibia were treated by continued skeletal traction. This method has now been abandoned almost completely because it seriously delays the rate of union. If the fracture is so unstable that it will redisplace even after perfect reduction and immobilisation in plaster it is better to use internal fixation.

union is seriously delayed. Thus the technique of continuous traction has been almost entirely abandoned in the treatment of these fractures. If the fracture is of such instability that after manipulation and immobilisation in plaster there is danger of serious redisplacement, it is better to perform an open operative reduction and fix the fragments with a plate and four screws, a bone graft and screws, or perhaps an intramedullary nail.

Replaster after two or three weeks—After the swelling has subsided a new plaster is nearly always needed. This should be almost completely unpadded—perhaps with one or two layers of stockinet beneath it—extending to the groin with the knee slightly flexed.

Wedging the plaster—If the alignment is not accurate it should be corrected after the plaster has set by wedging. The technique of such wedging of the plaster is described on page 171. It is of special value in

CHAPTER XXVIII

INJURIES OF THE ANKLE

The former classification of joint injuries into sprains dislocations and fracture-dislocations has no good foundation in theory or in practice"

—WATSON-JONES 1934 *

It has often been said by patients and no less often been denied by surgeons that it is worse to sprain an ankle than to break it There is some truth in the observation Especially was this so in earlier years when every capsular injury was described as a sprain no matter whether there had been simple stretching of a few fibres from which recovery was rapid and complete regardless of treatment or avulsion of ligaments which could not have been sustained except as part of a dislocation of the joint—at least a momentary dislocation which threatened all the perils and complications of any other dislocation Both these types of injury were grouped together as sprains and they were treated similarly by bandage or strapping massage or radiant heat and early mobilisation or weight bearing

There are still some surgeons who believe that every injury to a ligament should be treated by immediate exercise They argue that the stability of a joint is maintained by muscles and that without such protection ligaments soon give way and lengthen They quote the stretching of tarsal ligaments in paralytic flat foot, and the laxity of ligaments causing genu recurvatum which arises when a knee joint is immobilised too long in the fully extended position They point out that ligaments serve primarily as sensory end-organs transmitting afferent impulses when they are stretched so that the efferent response stimulates rapid muscle contraction by which to guard the joint They suggest therefore that torn ligaments are always protected if the tone of muscles is maintained and that there is no need for the added support of plaster

But clearly the sensory mechanism by which such physiological stretching initiates prompt muscle contraction cannot occur if a ligament is avulsed from bone Strain on the joint does not then stretch the ligament and set up a protective reflex—it merely increases the separation of avulsed fibres and delays repair just as surely as similar failure of protection would delay union of a fracture Redevelopment of muscle control by active exercise may be the only treatment needed for sprains but this is not so when ligaments are torn away and widely displaced from their normal attachments to bone

Two types of ligament injury—*Sprains and avulsions*—Formerly it was customary to define three types of joint injury 1) sprains 2) dislocations 3) fracture-dislocations They were often differentiated so sharply as to be considered in remotely separate parts of the same text Such a classification is basically wrong First there is no essential difference between a dislocation and a fracture-dislocation they must be considered together as

* From the Bradshaw Lecture given in the Royal College of Surgeons of England, 1934, on Injuries of Ligaments, not previously published, on which the first part of this chapter is based.

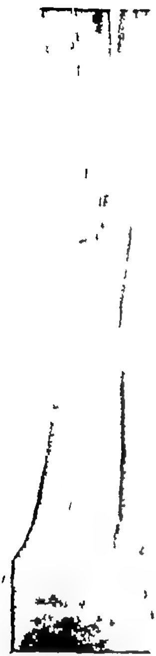


FIG 1270

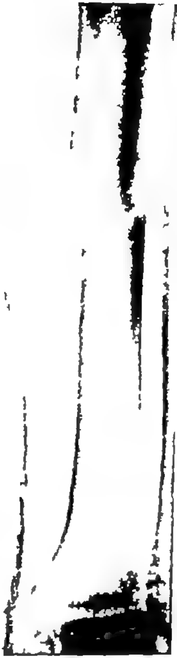


FIG 1271

FIG. 1272

The fallacy of an intact fibula preventing proper alignment or apposition of the fragments of a fractured tibia

A displaced fracture of the shaft of the tibia was manipulated and put in plaster Radiographs then showed that there was lateral angulation (Fig 1270) It was suggested that this could not be corrected without operation because the fibula was intact It was proposed that the fibula should be divided by osteotomy but this of course is nonsense The alignment was easily corrected by simple wedging of the plaster (Fig 1271) and the fracture united in perfect position (Fig 1272) Far too much stress has been placed on the supposed problem of the intact fibula, not only in such a matter as this but also in the treatment of fractures of the shaft of the tibia with delayed union or established non union There is no need at all to divide the fibula by osteotomy in any of these cases In recent fractures perfect alignment can be restored by simple wedging of the plaster In old un united fractures a simple bone grafting procedure succeeds without there being any need at all to osteotomise the fibula.

one type of injury In nearly every dislocation there is at least some bone injury varying from minor separation of marginal fragments to more serious comminution of the joint surfaces There is always a common principle of treatment namely to correct the displacement and immobilise the joint On the other hand there is wide variation in the principles and details of treatment of sprains and avulsions of ligaments A simple sprain with only stretching of capsular fibres and no instability of the joint is best treated by early movement and exercise whereas avulsion of a ligament from momentary dislocation must be treated by immobilisation for several weeks or months in order to prevent recurrent dislocation

One other point must be considered Even in severe injuries a ligament is seldom torn in the middle almost invariably it is avulsed from its proximal or distal attachment In being avulsed it may pull off a fragment of bone but this makes little difference and we should not perpetuate the old diagnosis of sprain fracture which was regarded as a mild variant of the harmless sprain When a fragment of bone is included with the avulsed ligament it is of course easier to recognise displacement and separation by radiographic examination Tilting of the bone fragment may indicate clearly the need for operative replacement For example when the medial malleolus is avulsed by traction through the medial ligament of the ankle operative treatment with removal of an interposed flap of periosteum and internal fixation by a suture or screw is often needed Similarly when a fragment of bone is avulsed from the base of a phalanx by the capsule of the interphalangeal joint early operation may be advisable But the same displacement of avulsed ligaments must be recognised even when there are no separated fragments of bone by which to make the recognition easy through radiographic study The medial ligament of the knee joint may be avulsed from the femoral condyle with curling and infolding or even interposition of its fibres in the joint and the diagnosis should still be established by clinical and radiographic examination so that the ligament and capsule may be replaced and sutured

Classification of joint injuries—From every point of view it is clear that we should abandon the old classification of joint injuries and adopt instead

1 Sprain of ligaments with simple stretching of fibres and normal stability of the joint
2 Avulsion of ligaments with or without fragments of bone from momentary dislocation of the joint
3 Dislocation and fracture-dislocation of the joint

It is only within recent years that the important distinction between sprains and avulsions of the lateral ligament of the ankle from inversion stress has been recognised * and even now there is often failure to distinguish sprains and avulsions of the medial and inferior tibio-fibular ligaments of the ankle from eversion stress (Figs 1278-1281) Still more is this so in injuries of the ligaments of other joints—the medial ligament of the knee the lateral

* It was, I think, first made in my fracture clinic at the Liverpool Royal Infirmary in 1925 and was described in the first edition of this book in 1940 when radiographic examination of the inverted foot was advised as a routine part of the investigation of all acute "sprain" as well as of "chronic sprains" which were in fact recurrent dislocations. In 1934 R. C Elmslie reported four cases of recurrent dislocation of the ankle and commented on the inversion x rays of the ankle taken by Dr Caldwell of members of his staff (*Ann Surg.*, 1934 100, 364)

fractures of the tibia because the slightest trace of medial or lateral angulation causes serious incapacity and whereas a surgeon may hesitate to remove a plaster and apply a new one with the object of correcting a few degrees of angulation fearing that some other displacement may arise he need not hesitate to use the wedging method with its accurate control and safety (Figs 1270 1272)

Preventing rigid clawing of the toes—Rigid transverse flat foot with rigid clawing of the toes often complicates leg fractures and may cause persistent disability long after the fracture has united (see page 46) In applying plaster to the forefoot there is a tendency to pull up the first and fifth metatarsal heads by the turns of bandage and to hyperextend the metatarso-phalangeal joints of the toes so that the transverse arch is convex towards the sole Even before the fracture was sustained many patients have had mobile transverse flat foot with clawing of the toes—symptomless because it was mobile and correctable After long immobilisation in the fault position with neglect of active exercise mobile clawing becomes rigi clawing the toes cannot be flexed to the ground With every ste body weight is carried through the metatarsal heads and there is cripplin pain and a sensation as of walking on small stones Two precautions ar needed to prevent this complication 1) the plaster over the forefoot shoul be so moulded that the metatarsal heads lie in their normal slightly arche position so that the metatarso phalangeal joints can be flexed 2) the toe must be exercised actively and flexed fully at the metatarso-phalange joints many times a day

Duration of immobilisation—After ten or twelve weeks if radiographi examination shows continuity of bone trabeculæ between the fragment the plaster is removed to allow clinical tests of union Union is soun when tenderness has disappeared when no pain is elicited by strainin the fracture and when there is no longer elasticity or springing of th fragments If union is not firm a complete plaster should be reapplie from the toes to the upper thigh with the knee slightly flexed The kne should not be straight because the tibia and femur can then rotate togethe and a plaster to the upper thigh does not prevent rotation strain of th fracture

Weight-bearing in plaster—Weight bearing should not be permitte until the fracture is firm to clinical tests When union is clinically firn but there is not yet sufficient radiographic evidence of consolidation for th plaster to be discarded a walking plaster may be applied. It extends fro the toes to the upper thigh with the knee slightly flexed. A sorbo rubbe pad may be fixed to the heel with strapping and a boot is fitted so th the patient dresses normally and walks several miles a day The full lengt plaster is not discarded until there is clinical and radiographic evidence (firm union of the fracture

Danger of short plaster and walking irons—A short below knee plast is not safe at any time Rotational movement of the upper fragment is n controlled by a short plaster and the strain delays consolidation or eve causes resorption of the newly formed callus thus giving rise to non unio Short irons and caliper splints are also unsafe If the callus is elastic a iron will not prevent secondary angulation indeed bandaging the limb t an outside iron actually produces angulation A fracture of the tibia is

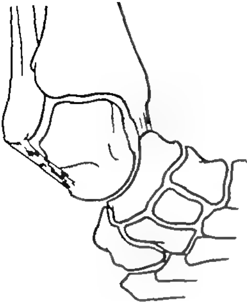


FIG. 1278

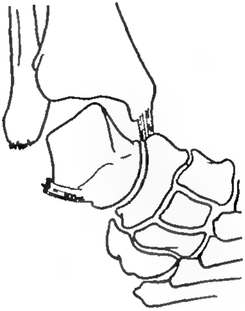


FIG 1279

Sprain of the lateral ligament of the ankle (Fig 1278) and avulsion of the lateral ligament with momentary dislocation (Fig 1279)

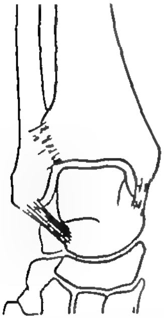


FIG 1280

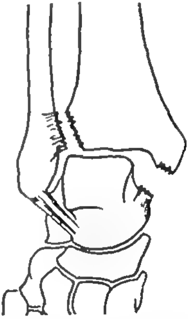


FIG 1281

Sprain of the medial ligament of the ankle and of the inferior tibio-fibular ligament (Fig 1280) and avulsion of these ligaments with momentary dislocation (Fig 1281).

ligament of the knee the rotator cuff of the shoulder the anterior ligaments and glenoid fibro-cartilage of the shoulder the posterior ligaments of the shoulder the medial ligament of the elbow the ligaments of the carpal joints the capsules of the finger joints the interspinous and apophyseal ligaments of the vertebræ and so on They are illustrated diagrammatically in Figures 1282 1291 In all these joints a true sprain threatens little more than adhesion formation and recovery is rapid and complete if muscle

either united so firmly that an iron is unnecessary or it is not soundly united and much greater protection is required

Disadvantage of continuous traction in fractures of the tibia—Traction on the tibia causes delay in union of fractures of the shaft The average delay in a reported series of 804 lower limb shaft fractures was in the region of four weeks[1] Even when excessive pull and distraction were avoided only 22 per cent of tibial fractures treated with traction united soundly in twelve weeks or less whereas 45 per cent of fractures treated without traction were united at that time If traction is unduly heavy and the fragments are allowed to distract the delay is much more serious Even if separation of the fragments amounts only to a quarter of an inch and even if it is corrected within a week or two few distracted fractures of the tibia unite in less than four months and most unite only after six or twelve months of continuous immobilisation

Effect of traction and distraction on the rate of union of 319 closed fractures of the tibia

Soundly united in	10 to 12 weeks.	12 to 16 weeks.	16 to 24 weeks.	24 to 48 weeks.
	Per Cent	Per Cent	Per Cent	Per Cent
Continuous immobilisation without traction	45	30	20	5
Continuous immobilisation with traction	22	21	52	5
Excessive pull and distraction	None	6	25	63

Effect of distraction and infection on the rate of union of 319 closed fractures of the tibia

United in	Less than 16 weeks.	16 to 24 weeks.	24 to 48 weeks.
	Per Cent	Per Cent	Per Cent
Closed fractures without traction	75	20	[illegible]
Closed fractures with distraction	6	23	63
Open fractures with infection	0	20	56

It is therefore clear that although light skeletal traction may sometimes be needed during the first week or two in serious open and infected fractures of the shaft of the tibia it should never be used in simple closed fractures If the fracture is so unstable that simple manipulation reduction with immobilisation in plaster does not suffice to prevent redisplacement it is better to use operative reduction and internal fixation

TREATMENT BY OPERATIVE REDUCTION AND INTERNAL FIXATION

The surgeon who proposes to avoid the delays of continuous traction by operating on a fracture of the shaft of the tibia must remember that infection of the wound causes even more serious delay Consider the table which compares the influence of distraction and infection on the rate of union

[1] Watson-Jones R & Coltart W D "Critical Review Slow Union of Fractures." Brit J Surg 1943, 30 [illegible]

FIG 128_ FIG 1283

Sprain and avulsion of the medial ligament of the knee joint.

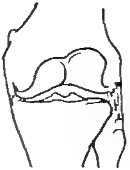


FIG 1284 FIG. 1285

Sprain and avulsion of the lateral ligament of the knee joint.

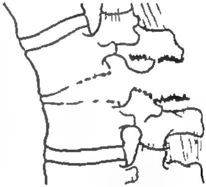


FIG 1286 FIG. 1287

Sprain and avulsion of the interspinous and apophysial ligaments in injuries of the spine Note that with simple sprain of ligaments the associated fractures are stable and safe (Fig 1286); with avulsion of the ligaments, fractures are unstable and unsafe (Fig 1287).

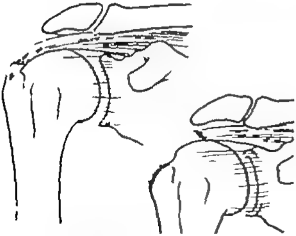
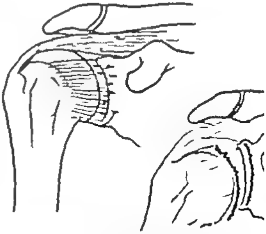


FIG. 1288 1289

'prain and avulsion of the supra pinatus tendon ind rotator cuff of the houlder Note from the ext how difficult i the differential diagnosis.



FIGS 1290-1291

Sprain and avulsion of the anterior capsule a glenoidal labrum, the essential patholog anatomy of acute as well as recurrent dislocati

of fractures of the shaft of the tibia It is evident that distraction and infection are equally harmful in delaying union but whereas the penalty of distraction is limited to slow union the penalty of infection may also include chronic osteomyelitis with persistent discharge from sinuses and established non union There is no justification for the treatment of fractures of the shaft of the tibia by operative reduction and internal fixation except in the hands of surgeons who can rely on first intention healing of

Fig 1[illegible]3

Oblique fracture shaft of tibia treated by open reduction and transfixion with a screw Inset shows the best position that could be secured by closed reduction. Unless internal fixation had been employed continuous traction for several weeks would have been necessary with the disadvantage of causing slow union

the wound with complete certainty It is not enough that most wounds heal without infection every wound must heal without infection Let it be perfectly clear that despite all recent advances there are still many infections that cannot be controlled by chemotherapy No surgeon is at liberty to undertake operative reduction and internal fixation of fractures of the shaft of the tibia unless there is a near-certainty that the wound will not be infected There can be few greater disasters than to convert a closed fracture into an open infected fracture with its sequestration and persistent non union If you will look back to pages 214 217 and Figures 362 365 it will at once be evident how lamentable may be the consequence

control is maintained and stiffness is prevented—but in all of them avulsion of the capsule threatens recurrent dislocation unless there is suitable protection at the time of the first injury The significance of intact ligaments in maintaining stability is particularly evident in vertebral injuries where fractures are usually safe and stable if there has been no more than a sprain, but are often unsafe and unstable if there has been avulsion of ligaments

INJURIES OF THE LATERAL LIGAMENT OF THE ANKLE JOINT

The ligaments on the lateral side of the ankle joint are protected by the peroneal muscles but they may be stretched or avulsed by sudden inversion twists such as occur from unexpected irregularities in the ground tripping off the edge of a curb running and jumping in a field or even just from walking in shoes with heels badly worn on the outer side Whatever the degree of injury to the ligament there is swelling and œdema ecchymosis on the lateral side of the joint tenderness on pressure and pain if the foot is forcibly inverted We will consider (1) sprains of the lateral ligament (2) avulsions of the lateral ligament from momentary dislocation (3) avulsions of the lateral ligament causing recurrent dislocation

(1) SPRAIN OF THE ANKLE JOINT

A true sprain of the lateral ligament is a minor injury and recovery should be complete within two or three weeks It is important to be sure that the injury is in fact no more than a sprain When the foot is held inverted the lateral margin of the talus should be felt in its undisplaced position immediately in front of the malleolus without any gap between This must of course be confirmed by radiographic examination of the inverted ankle A crêpe bandage should be applied firmly the turns passing from within outwards round the inner margin of the foot under the sole and across the front of the ankle to the inner side of the leg in such a way that inversion movement is controlled—the support of the bandage being greatest round the ankle joint itself over the point of the heel and around the malleoli. It is better to use crêpe bandage rather than adhesive strapping which often causes soreness of the skin or even severe dermatitis Non weight bearing exercises within the limits of pain should be practised immediately and weight bearing may be allowed as soon as the acute symptoms have subsided. The bandage should usually be kept in position for about ten days but if there is still swelling and œdema an elastic anklet may be worn for several weeks longer

Treatment by procaine injection—Infiltration of the stretched ligament with about 5 c c of 1 per cent procaine has been advised [1, 4] The immediate analgesia allows the patient to move the joint and walk without pain After some hours the pain often returns and for the time being it may even be worse but within twenty four to forty-eight hours the symptoms often disappear It was believed by Leriche that such an injection reduced the tendency to swelling and œdema and by permitting earlier functional activity minimised adhesion formation and accelerated recovery I must say that striking as may be the results of procaine infiltration of a sprained capsule

Leriche R *Pr med* 1936, 44, 89
Leriche R & Froehlich, F *Pr med* 1936, 44, 1065.
Campbell, W C *J roy nav med Serv* 1938 24, 48
Coltisbone H, *Lancet* 1939 2, 5..

of infection and how even a minor degree of persistent infection causes non union Let no surgeon even think of using operative reduction with metallic internal fixation of fractures of the shaft of the tibia until he has a certain experience of non touch technique with avoidance of operative infection and takes care not to operate through the site of lymphatic drainage of recently healed wounds or pressure sores

Screw fixation of oblique and spiral fractures—In oblique and spiral fractures internal fixation is best secured by one or perhaps two screws transfixing the fragments Through a four or five inch incision the fracture is reduced and the bone ends are held in a suitable bone clamp The axis in which the screw will lie must be selected carefully so that an equal thickness of bone will be engaged in each fragment To avoid subcutaneous projection the screw heads are countersunk into the bone[1] (Fig 1273) The length of drill hole must be measured accurately Non ionisable metal screws of the correct length are driven home the stability of reduction is tested the periosteum is closed the skin sutured and a padded plaster applied. The plaster is changed to an unpadded cast after two or three weeks Weight bearing in plaster may be permitted after about six weeks and the plaster can usually be discarded in ten or twelve weeks

Plating or bone-grafting transverse fractures—In transverse fractures it may be possible to use a single screw but the technique is more hazardous and selection of the correct axis for the screw is more difficult than in spiral fractures For this reason transverse as well as comminuted fractures should usually be treated by means of a bone or metal plate and four screws A plate of non ionisable metal causes no reaction and if it is fixed on the lateral surface of the bone deep to the anterior tibial muscles no thickening or tenderness remains over the subcutaneous surface of the shin A bone plate cut from the opposite or the same tibia and fixed to the fractured bone as an onlay graft is still better Even in recent fractures the blood supply may be so impaired that union is slow The decision to operate and fix the fragments having been made it is therefore advisable to use a device which will aid repair and accelerate union After the fracture has been reduced and the accuracy of alignment and rotational position have been confirmed a full thickness cortical and medullary graft half to three-quarters of an inch wide is fixed to the freshened lateral surface by four stainless-steel screws Several examples were illustrated in the first volume

Fixation of tibial fractures by an intramedullary nail—Intramedullary nail fixation which is so successful in fractures of the shaft of the femur fractures of the upper shaft of the ulna and fractures of the shaft of the humerus where insertion of a straight nail is so easy has also been advocated in fractures of the shaft of the tibia where the insertion of a curved nail through the upper tibial tuberosity down the shaft of the bone is far from easy We are bound to say that despite all the advertising of manufacturers of nails who in their wanton publicity have tried to create medical journals of their own it is not yet clear that there is real merit in the attempt to secure fixation of fractures of the shaft of the tibia by intramedullary nailing

[1] Ronald, A. [illegible] Fixation of Old Oblique and Spiral Fractures of the Tibia by a Single Vitallium Screw" *Proc Roy Soc Med* (Section of Orthopaedics), 194[illegible], 35, 763.

Fig. 1282

Fig. 1283

Sprain and avulsion of the medial ligament of the knee joint.

Fig. 1284

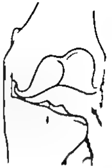


Fig. 1285

Sprain and avulsion of the lateral ligament of the knee joint

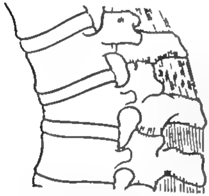


Fig. 1286

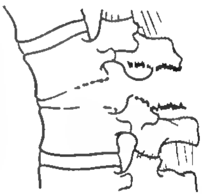
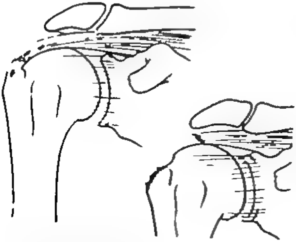


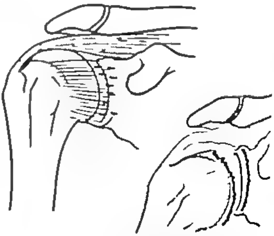
Fig. 1287

Sprain and avulsion of the interspinous and apophysial ligaments in injuries of the spine. Note that with simple sprain of ligaments the associated fractures are stable and safe (Fig. 1286); with avulsion of the ligaments, fractures are unstable and unsafe (Fig. 1287).



Figs. 1288-1289

Sprain and avulsion of the supraspinatus tendon and rotator cuff of the shoulder. Note from the text how difficult is the differential diagnosis.



Figs. 1290-1291

Sprain and avulsion of the anterior capsule and glenoidal labrum, the essential pathological anatomy of acute as well as recurrent dislocation.

FRACTURES OF THE SHAFT OF THE TIBIA WITH SLOW UNION AND NON UNION

Even when the dangers of traction and distraction have been avoided the blood supply of the tibia is such that fractures in the lower half of the shaft of the bone may unite very slowly (see page 10) If this is recognised and immobilisation is suitably prolonged sound union by bone with perfect functional recovery can still be relied upon [1] The temptation to change the method of treatment must be resisted requests to shorten the plaster must be refused and complete immobilisation in a full length plaster should be continued for three six nine or even twelve months

FIG. 1274

FIG. 1275

Un united fracture of lower shaft of tibia before and after correction of deformity and inlaying of bone graft from the opposite tibia.

If union is still delayed it may be wise to do a bone grafting operation. It will be recognised from earlier chapters that the essentials of such an operation are 1) to refreshen the sclerosed fracture-surfaces 2) to implant cancellous fragments of bone which have vital osteogenetic properties and 3) to ensure that the fragments are immobilised and protected from shearing and rotational strains Sometimes there is such complete lack of fixation of the fragments that the internal fixation of a whole-thickness onlay or inlay graft is needed (Figs 1274 1275 also Figs 457 460, 501 520 523 528 530 532 539 But often there is already a slender bridge of united bone and all that is needed is to refreshen the surfaces and without tearing them apart to excavate a hollow at the level of fracture and pack into it fragments of cancellous bone cut from the ilium Such a case is shown in Figures 1276-1277 . The apposition and alignment of the fragments

Bechtman, A. M "Percussion Treatment Fractures of Leg, Delayed Union." Amer J. S[illegible] 1934, x 29 490
Lundgren, C. Fractures of Tibial Shaft (Study of 3 [illegible] Cases)." Act ch [illegible] 1940, [illegible], Supplement [illegible]

control is maintained and stiffness is prevented—but in all of them avulsion of the capsule threatens recurrent dislocation unless there is suitable protection at the time of the first injury. The significance of intact ligaments in maintaining stability is particularly evident in vertebral injuries where fractures are usually safe and stable if there has been no more than a sprain but are often unsafe and unstable if there has been avulsion of ligaments.

INJURIES OF THE LATERAL LIGAMENT OF THE ANKLE JOINT

The ligaments on the lateral side of the ankle joint are protected by the peroneal muscles but they may be stretched or avulsed by sudden inversion twists such as occur from unexpected irregularities in the ground, tripping off the edge of a curb, running and jumping in a field or even just from walking in shoes with heels badly worn on the outer side. Whatever the degree of injury to the ligament there is swelling and œdema, ecchymosis on the lateral side of the joint, tenderness on pressure and pain if the foot is forcibly inverted. We will consider (1) sprains of the lateral ligament, (2) avulsions of the lateral ligament from momentary dislocation, (3) avulsions of the lateral ligament causing recurrent dislocation.

(1) SPRAIN OF THE ANKLE JOINT

A true sprain of the lateral ligament is a minor injury and recovery should be complete within two or three weeks. It is important to be sure that the injury is in fact no more than a sprain. When the foot is held inverted the lateral margin of the talus should be felt in its undisplaced position immediately in front of the malleolus without any gap between. This must of course be confirmed by radiographic examination of the inverted ankle. A crêpe bandage should be applied firmly, the turns passing from within outwards round the inner margin of the foot, under the sole and across the front of the ankle to the inner side of the leg in such a way that inversion movement is controlled—the support of the bandage being greatest round the ankle joint itself, over the point of the heel and around the malleoli. It is better to use crêpe bandage rather than adhesive strapping which often causes soreness of the skin or even severe dermatitis. Non weight bearing exercises within the limits of pain should be practised immediately, and weight bearing may be allowed as soon as the acute symptoms have subsided. The bandage should usually be kept in position for about ten days, but if there is still swelling and œdema an elastic anklet may be worn for several weeks longer.

Treatment by procaine injection—Infiltration of the stretched ligament with about 5 c.c. of 1 per cent procaine has been advised.[1-4] The immediate analgesia allows the patient to move the joint and walk without pain. After some hours the pain often returns and for the time being it may even be worse, but within twenty four to forty-eight hours the symptoms often disappear. It was believed by Leriche that such an injection reduced the tendency to swelling and œdema, and by permitting earlier functional activity minimised adhesion formation and accelerated recovery. I must say that, striking as may be the results of procaine infiltration of a sprained capsule

Leriche, R. Pr. méd. 1936, 44, 92
Leriche, R., & Froehlich, J. Pr. méd. 1936, 44, 1065.
Campbell, W. G. J. roy. nav. med. Serv. 1938, 24, 48
Cullumbine, H. Lancet 1939, 2, 53

of infection and how even a minor degree of persistent infection causes non union Let no surgeon even think of using operative reduction with metallic internal fixation of fractures of the shaft of the tibia until he has a certain experience of non touch technique with avoidance of operative infection and takes care not to operate through the site of lymphatic drainage of recently healed wounds or pressure sores

Screw fixation of oblique and spiral fractures—In oblique and spiral fractures internal fixation is best secured by one or perhaps two screws transfixing the fragments Through a four or five inch incision the fracture is reduced and the bone ends are held in a suitable bone clamp The axis in which the screw will lie must be selected carefully so that an equal thickness of bone will be engaged in each fragment To avoid subcutaneous projection the screw heads are countersunk into the bone[1] (Fig 1273) The length of drill hole must be measured accurately Non ionisable metal screws of the correct length are driven home, the stability of reduction is tested, the periosteum is closed the skin sutured and a padded plaster applied. The plaster is changed to an unpadded cast after two or three weeks Weight bearing in plaster may be permitted after about six weeks and the plaster can usually be discarded in ten or twelve weeks

Plating or bone-grafting transverse fractures—In transverse fractures it may be possible to use a single screw, but the technique is more hazardous and selection of the correct axis for the screw is more difficult than in spiral fractures For this reason transverse as well as comminuted fractures should usually be treated by means of a bone or metal plate and four screws A plate of non ionisable metal causes no reaction and if it is fixed on the lateral surface of the bone deep to the anterior tibial muscles no thickening or tenderness remains over the subcutaneous surface of the shin A bone plate cut from the opposite or the same tibia and fixed to the fractured bone as an onlay graft is still better Even in recent fractures the blood supply may be so impaired that union is slow The decision to operate and fix the fragments having been made it is therefore advisable to use a device which will aid repair and accelerate union After the fracture has been reduced and the accuracy of alignment and rotational position have been confirmed a full thickness cortical and medullary graft half to three-quarters of an inch wide is fixed to the freshened lateral surface by four stainless-steel screws Several examples were illustrated in the first volume

Fixation of tibial fractures by an intramedullary nail—Intramedullary nail fixation which is so successful in fractures of the shaft of the femur fractures of the upper shaft of the ulna and fractures of the shaft of the humerus where insertion of a straight nail is so easy has also been advocated in fractures of the shaft of the tibia where the insertion of a curved nail through the upper tibial tuberosity down the shaft of the bone is far from easy We are bound to say that despite all the advertising of manufacturers of nails who in their wanton publicity have tried to create medical journals of their own it is not yet clear that there is real merit in the attempt to secure fixation of fractures of the shaft of the tibia by intramedullary nailing

[1] Ronald, A. [illegible] of Oblique and Spiral Fractures of the Tibia by [illegible] Single [illegible] Screw *Proc Roy Soc Med* (Sect of Orthopaedics) 1942, 35, 63

of the shoulder joint the merit of similar infiltration of sprained ligaments of the ankle joint is not proved

Adhesion formation—The formation of adhesions in and around a sprained lateral ligament of the ankle is minimised by preventing swelling and œdema by firm crêpe bandage elevation of the limb and early active non weight bearing exercise If adhesions still develop the patient may complain of continued pain on the lateral side of the joint with weakness and giving way It is sometimes wise to crook the outer side of the heel one-eighth of an inch or to float-out the heel so as to broaden it on the outer side [1] while the patient continues active exercise Very occasionally it may even be necessary to give a short anæsthetic and manipulate the foot but this is very seldom needed Almost invariably it should be possible to regain a normal range of movement by active exercise alone

2) AVULSION OF THE LATERAL LIGAMENT WITH MOMENTARY DISLOCATION OF THE JOINT

The possibility of complete avulsion of the anterior and middle bands of the lateral ligament from the malleolus should be suspected in every severe

Fig 1202

Fig 1203

Complete avulsion of the lateral ligament of the ankle joint with momentary dislocation The joint may seem to be normal unless it is examined with the foot in full inversion then there is clinical evidence of the talus separating from the malleolus (Fig 1203) This should, of course be confirmed by taking radiographs of the inverted foot (Figs 1204 1207)

inversion injury of the ankle joint The severity of swelling and ecchymosis may give an indication as to the nature of the injury but the important clinical sign is abnormal mobility of the talus on inversion movement of the foot

Clinical diagnosis—In a normal foot the lateral surface of the body of the talus can be felt just in front of the body of the malleolus and it remains in close contact with the malleolus even when the foot is inverted at the

[1] Hart W D "Sprained Ankle" Brit med J, 19 1 2,

FRACTURES OF THE SHAFT OF THE TIBIA WITH SLOW UNION AND NON UNION

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Fig. 1274

Fig 1275

Un-united fracture of lower shaft of tibia before and after correction of deformity and inlaying of bone graft from the opposite tibia.

If union is still delayed it may be wise to do a bone-grafting operation It will be recognised from earlier chapters that the essentials of such an operation are 1) to refreshen the sclerosed fracture surfaces 2) to implant cancellous fragments of bone which have vital osteogenetic properties and 3) to ensure that the fragments are immobilised and protected from shearing and rotational strains Sometimes there is such complete lack of fixation of the fragments that the internal fixation of a *whole-thickness* onlay or inlay graft is needed (Figs 1274 1275 also Figs 457 460 501 520 523 525 530 532 539 But often there is already a slender bridge of united bone and all that is needed is to refreshen the surfaces and without tearing them apart to excavate a hollow at the level of fracture and pack into it fragments of cancellous bone cut from the ilium Such a case is shown in Figures 1276 1277 The apposition and alignment of the fragments

Bechtman, A. M. "Percussion Treatment Fractures of Leg, Delayed Union." *Amer J Surg.*, 1933, n.s. 20 290.
Lundgren, A "Fractures of Tibial Shaft (Study of 3 9 Cases)." *Acta chirurg scand.*, 1936 78, Supplement 42.

subtalar joint On the other hand if the lateral ligament is avulsed from bone inversion movement occurs at the ankle joint as well as at the subtalar joint and it is easy to feel the talus tilt and move away from the malleolus so that a well-defined sulcus appears between the two bones, deep enough to admit the tip of the examiner's finger (Fig 1293) In performing this test there is no need to infiltrate the hæmatoma with procaine, the patient is unable to prevent the displacement by the resistance of his peroneal muscles and if the test is done gently but firmly it does not cause severe pain Minor degrees of tilting of the talus from avulsion of the lateral ligament cannot always be recognised clinically, and routine radiographic examination of the inverted foot is essential

Radiographic diagnosis—Anteroposterior radiographs are taken of the ankle joint with the foot in the fully inverted position If the injury has been a simple sprain the talus remains quite stable in the tibio-fibular mortice (Fig 1294) The slightest degree of inward subluxation arising from avulsion of the lateral ligament from the malleolus will be shown in the tilted position of the talus (Fig 1295) If avulsion is complete well marked tilting of the talus out of the tibio-fibular mortice is evident (Fig 1296) If such an injury is not suitably treated by immobilisation for several weeks recurrent dislocation of the ankle develops with still greater tilting (Fig 1297) This radiographic study can be misleading unless the foot is inverted fully It is not a question of adducting the forefoot but of inverting the heel This should always be done by the surgeon himself because a radiographer or nurse may be afraid of doing harm by applying undue force Just as with the clinical test described above the manœuvre causes little or no pain if it is done gently and firmly Nevertheless some surgeons prefer to infiltrate the area with procaine in order to be sure that they have overcome all muscle resistance and have displayed the full degree of tilting of the bone

Treatment—Complete immobilisation in plaster is essential A light unpadded plaster cast is applied with the foot at right angles to the leg the heel being in the neutral position or pushed gently outwards in order to be sure that the position of the talus is normal The plaster cast should be renewed after two or three weeks when swelling has subsided There is no need for the patient to be recumbent A plaster boot may be fitted so that the patient can pursue ordinary activities but immobilisation in plaster should be continued for ten weeks In a few cases we have tested the stability of the ankle after immobilisation for eight weeks or even only for six weeks but it has been found that healing is seldom sound unless it is continued for about ten weeks If this is done repair will be complete and normal stability of the ankle will be regained

Compound dislocation of the talus without malleolar fracture—When it is recognised that avulsion of the anterior and medial bands of the lateral ligament from momentary dislocation tears every capsular tissue on the lateral side of the joint—so that if exposed by making an incision through the skin the articular cartilage is at once seen—it is evident that occasionally in very severe injuries the skin may also be lacerated so that a compound dislocation is sustained without malleolar fracture [1] (See also pages 835-839)

[1] North, J P "Compound Dislocation Talus without Malleolar Fracture" J Bone Joint Surg., 1938, 20, [illegible]

was satisfactory without disturbing the position, or the bridge of union which was developing the antero medial aspect of the fracture site was excavated and packed tightly with iliac bone chips The fracture united within three months

Fig 1276

Fig 1277

Un united fracture of the shaft of the tibia treated successfully by simple refreshening of the surfaces with impaction of fragments of cancellous bone cut from the ilium

Double tibio-fibular synostosis—When a large part of the shaft of the tibia has been destroyed by virulent infection and dense avascular scar tissue lies between the fragments it may be better to relieve the disability by double tibio fibular synostoses The upper shaft of the fibula is grafted to the upper tibial fragment and the lower shaft of the fibula is similarly fixed to the lower tibial fragment [1,2] The fibula becomes a weight bearing bone and undergoes a remarkable degree of hypertrophy

[1] Girdlestone, G R and Foley, W B Extensive Loss of Tibial Diaphysis—Tibio-fibular Grafting. *Brit J Surg* 1932 20, 467

[2] Carrell, W B Treatment of Un-united Fracture of Tibia by Transposition of Fibula of Same Leg. *J Bone Joint Surg* [illegible] 20 [illegible]

Fig. 1294

Fig. 1295

After simple sprain of the lateral ligament of the ankle radiographs taken with the foot inverted *show normal stability of the talus within the tibio-fibular mortice (Fig. 1294)* or at most a very slight tilt (this, incidentally, is my own ankle which has never caused any symptoms—Fig. 1295).

Fig. 1296

Fig. 1297

After complete avulsion of the lateral ligament of the ankle from the malleolus, radiographs taken with the foot inverted show tilting of the talus (Fig. 1296); and if this is not treated in the beginning by complete immobilisation in plaster so that recurrent dislocation develops, the tilt of the talus when the foot is inverted is still more marked (Fig. 1297).

3) RECURRENT DISLOCATION OF THE ANKLE JOINT

When an avulsed lateral ligament has been wrongly treated as a simple sprain by strapping with early mobilisation and massage, recurrent dislocation * of the talus often arises The patient complains of insecurity weakness and giving way of the joint It is impossible to walk in narrow heeled shoes or in any shoe with a heel worn down on the outer margin On uneven surfaces a sudden inversion twist may actually throw the patient to the ground The wearing of ankle straps bandages or boots may not control the disability and the patient learns to walk cautiously watching for irregularities Games and recreations become impossible

Diagnosis—Routine clinical and radiographic examination show no abnormality and the nature of the disability often passes unrecognised Many patients with this disability have been treated for months or years by massage faradic stimulation and manipulation with a diagnosis of weak ankle adhesions chronic sprain or even neurasthenia and functional disorder With one hand on the leg and the other grasping the foot the heel is inverted and the forefoot adducted It is then obvious that the talus tilts inwards and forwards leaving a well-defined sulcus immediately in front of the malleolus where the resistance of the bone should be felt The diagnosis is confirmed by radiographic examination made while the surgeon holds the foot fully inverted While holding the foot for such x rays the surgeon should of course protect his own hands with rubber gloves

Non-operative treatment—The displacement can sometimes be controlled by an outside crooked and splayed heel combined with regular exercises for development of the peroneal muscles It may even be suggested that the patient should use permanently an inside iron and outside T-strap but this is far too heavy a price to pay Operative reconstruction of the lateral ligament is better

Operative reconstruction of the lateral ligament—The operation I have used is a combined tenodesis and ligament reconstruction using the tendon of peroneus brevis (or occasionally when a greater length of tendon is needed peroneus longus) It has always been successful in a series of nearly one hundred cases A vertical incision is made behind the lower shaft of the fibula extending about one inch below the tip of the lateral malleolus The defect in the capsule of the ankle joint is obvious as soon as the deep fascia is divided and retracted The peroneus brevis tendon is dissected from its muscle belly and the muscle fibres are sutured to the tendon of peroneus longus so that the power of active eversion will not be impaired The tendon is freed as far as the lateral malleolus but the annular fibres holding it in position behind this bone are not disturbed A quarter inch hole is drilled horizontally from the posterior to the anterior margin of the

Traumatic dislocation or subluxation? Some surgeons insist that this injury should be described as a recurrent *subluxation* and not a recurrent *dislocation* Strictly dislocation is a joint displacement in which the bones are completely separated from each other whereas subluxation is a displacement in which the bones remain partly in contact. This distinction has special significance in congenital dystrophies of joints, notably for example in congenital subluxations and dislocations of the hip But injuries to joints cause so wide a range of displacement of the bones, from total separation lasting only a moment which is spontaneously reduced, to every degree of persistent or recurrent displacement that it is better to think only of traumatic dislocation while recognising that there is an imperceptible merging of every degree and type of displacement—momentary temporary permanent or recurrent

Fig 1311

Recurrent dislocation of the peroneal tendons which slip to and fro over the lateral margin of the malleolus.

Fig 1312

A thick bone flap is cut from the subcutaneous surface of the lateral malleolus with its periosteal and soft tissue attachments preserved so that there will be no interference with the blood supply The veneer or sliver of bone is swung back so that it lies over the peroneal tendons and deepens the peroneal groove It is held in position by simple catgut suture The ankle is then protected in plaster for two months.

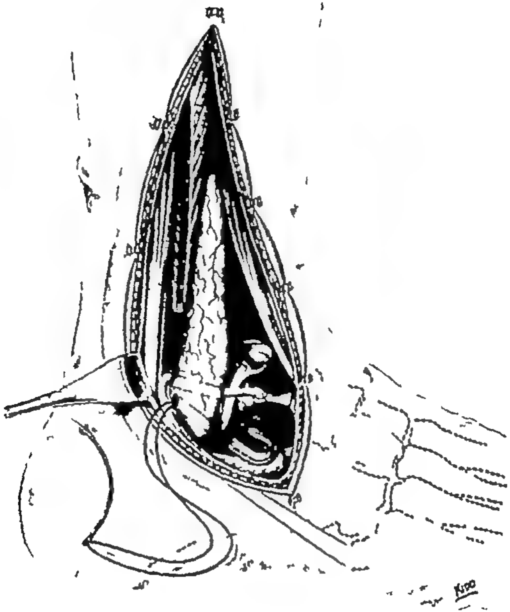


FIG. 1208

Watson-Jones's operation for recurrent dislocation of the ankle joint. The peroneus brevis tendon is dissected from its muscle, which is stitched to the peroneus longus tendon and passed through drill holes in the fibula and talus to lie in the normal position of the anterior and middle bands of the lateral ligament. The new ligaments are protected by the tenodesis between the base of the fifth metatarsal and the lateral malleolus.

CLASSIFICATION OF FRACTURES AND FRACTURE DISLOCATIONS OF THE ANKLE JOINT

We have already discussed sprains of the ankle and must now consi malleolar fractures as well as some allied fractures of the shaft of the fib in relation to the displacements that may arise It is far from easy to f a simple classification of these injuries There are not just hundred there are hundreds of thousands of variants of ankle joint injury includ sprains ligament-avulsions fractures dislocations all in combination w displacement outwards displacement backwards displacement inwa and displacement forwards Try it for yourself Take it that there just ten or twelve injuries any one of which may be associated with a other such as fracture of the medial malleolus avulsion of the med ligament fracture of the lateral malleolus, avulsion of the lateral ligame fracture of the lower shaft of the fibula rupture of the inferior tibio-fibu ligament avulsion of tibial fragments posterior marginal fracture of t lower end of the tibia and so on and you will find that the permutati are well over three millions The classification of Ashurst [1] is time honour but it was devised thirty years ago and cannot now be accepted With t invaluable aid of Philip Wiles and Crawford Adams a classification h been prepared it has been made as simple as possible (Figs 1323 1340)

1 Avulsion of the ligaments of the ankle from momentary dislocation
2 Avulsion of the ligaments of the ankle joint with malleolar fracture
3 Other malleolar fractures without displacement
4 Fractures of the ankle joint with lateral or postero lateral dislocati
5 Fractures of the ankle joint with medial or postero-medial dislocati
6 Fractures of the ankle joint with forward dislocation

1. Avulsion of the ligaments of the ankle joint from momenta dislocation—These injuries have been considered If the lateral ligament torn from the lateral malleolus by inversion stress or the medial ligament avulsed from the medial malleolus by eversion stress or if the infer tibio fibular ligament is torn from the tibia the ankle joint should protected in plaster for about ten weeks because otherwise there w be recurrent dislocation Such tearing of the lateral medial or infer tibio-fibular ligaments may of course be associated with avulsion fragments of bone but the basic principle of treatment remains the same there must be safe protection in plaster for two or three months if recurre displacement is to be avoided

2. Avulsion of the ligaments of the ankle joint with malleol fractures—In being avulsed the lateral medial or inferior tibio fibul ligaments of the ankle joint may tear off a fragment of bone These injuri should also be treated by protection in plaster for two or three months later displacement is to be avoided Sometimes the separated bone fragmen are tilted or displaced and there may be interposition of flaps of periosteu or of other soft tissues which prevent firm union by bone Operative treatme is usually needed sometimes with the internal fixation of a screw (Fig 1313 1316)

[1] Ashurst and Bromer "Classification and Mechanism of Fractures of the Ankle" Arch Surg 1922 4, 1

malleolus emerging at the point where the anterior band of the lateral ligament is normally attached A second hole is drilled vertically in the outer margin of the neck of the talus adjacent to the articular surface, emerging in the roof of the sinus tarsi The tendon is guided through these two drill holes and stitched to the periosteum over the tip of the lateral malleolus where the middle band of the lateral ligament is normally attached More secure fixation is possible if a second drill hole can be made in the malleolus from this point upwards and backwards so that the tendon is stitched to itself behind the malleolus The wound is closed and the foot is immobilised in plaster for about eight weeks Weight-bearing is permitted after the change of plaster at the second or third week

In this operation the object of the tenodesis, which is provided by the unexposed part of the tendon between the base of the fifth metatarsal and the lateral malleolus is to protect the new ligaments by preventing excessive inversion strain and this part of the tendon should not be unduly tight The new ligaments themselves should be fixed tightly between the talus and malleolus in the normal position of the original ligaments The only real problem in the operative technique is the choice of a site for the drill hole in the neck of the talus On one or two occasions this was made too close to the margin of the bone and while the tendon was being tightened it pulled through the thin wall of the bone and only with some difficulty was it stitched to the ligaments within the sinus tarsi

INJURIES OF THE MEDIAL LIGAMENT OF THE ANKLE JOINT AND OF THE INFERIOR TIBIO-FIBULAR LIGAMENT

It is curious that whereas forcible inversion of the ankle joint so often causes injury to ligaments without fracture of bone the opposite stress of eversion of the ankle joint commonly causes fracture of bone without serious injury to ligaments. This is of course a generalisation We shall soon have to consider all the combined ligament and bone injuries that arise from abduction-external rotation strains but the most frequent of them is a fracture of the lateral malleolus or lower shaft of the fibula without displacement Very seldom does forcible eversion of the foot cause only rupture of the medial ligament and the inferior tibio-fibular ligament but it is for the very reason that the injury is somewhat unusual that the surgeon must be alert to recognise it These ligament injuries are often overlooked and serious disability then arises Simple sprains accompanying fracture of the lateral malleolus or lower shaft of the fibula are of no special significance What is important is to recognise avulsion of the medial ligament and of the inferior tibio-fibular ligament with lateral displacement of the talus separation of the lower ends of the tibia and fibula with widening of the ankle mortice If this is left uncorrected there will be an unstable and unsafe ankle a *sloppy joint* in which it is only a matter of time before degenerative osteo-arthritis supervenes

Avulsion of the medial ligament of the ankle and of the inferior tibio-fibular ligament—This association of ligament injuries from eversion stress which may occur without fracture of bone is difficult to recognise clinically but is shown quite clearly in radiographs The important sign is widening of the joint space between the body of the talus and the medial malleolus which is

Fig 1313

Fig 1314

Fracture of the medial malleolus from avulsion of the medial ligament with interposition of a flap of periosteum (Fig 1313) Through a short incision the periosteal flap was removed and the malleolu was fixed by means of a screw

Fig 1315

Fig 1316

Fracture of the medial malleolus with periosteal interposition, treated by replacement of the periosteum and screwing of the malleolus.

Fig. 1317

Fig. 1318

If in these fractures of the medial malleolus the interposed flap of periosteum is not removed, non union results (Fig 131) and a bone grafting operation may then be needed (Fig 1318)

shown clearly in Figure 1299 It so happens that in this particular case there was also an undisplaced spiral fracture of the fibula but the important injury which threatened permanent disability was the avulsion of the medial and inferior tibio fibular ligaments It will be noted that separation of the tibia and fibula at the tibio fibular joint is often concealed because at this level the bones overlap An oblique projection would disclose it more clearly —but it is enough to see that the body of the talus does not fit snugly against the medial malleolus Such lateral displacement of the talus cannot occur

FIG 1299

The important injury here is the rupture of the medial ligament and of the inferior tibio-fibular ligament, permitting diastasis and thus explaining the abnormally wide joint space between the talus and the medial malleolu The spiral fracture of the fibula is incidental. Thi is a most un table injury calling for very great care in treatment.

unless there is corresponding displacement of the lateral malleolus or failing that separation or diastasis at the inferior tibio-fibular joint

Conservative treatment—This displacement of the ankle joint is difficult to control by conservative measures Some surgeons have even said that redisplacement cannot be prevented by conservative treatment alone but this is not true A closely fitting plaster should be applied while strong lateral compression is maintained the surgeon gripping the ankle with the palms of his hands over the malleoli and maintaining strong pressure of the fibu against the tibia while the plaster sets The pressure should be from t curve of the palms of the surgeon s hands round the malleoli rather th from a direct thrust over the bones themselves which might cause pressu sores A new plaster should be applied after ten or fourteen days wh swelling has subsided as well as a third after three or four weeks and perha

Fig 1319

Fracture-dislocation of the ankle joint in which a slender intramedullary pin was used [to fix] the fragments of the lateral malleolus—driven from the tip of the malleolus into the sh[aft of] the fibula—as well as a screw in the medial malleolus. The intramedullary pin [was] removed later

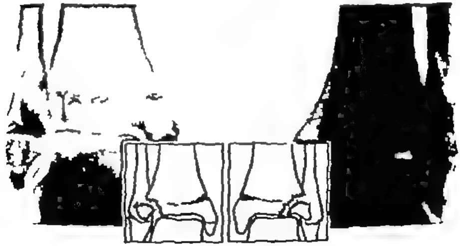


Fig 1320

Avulsion of the inferior tibio-fibular ligament with a fragment of bone from the tibi[a]. Operative replacement of the displaced bone fragment is sometimes needed. There is [no] need for internal fixation beyond simple suture of the torn periosteum and ligament

FIG. 1300

FIG 1301

An apparently simple rupture of the medial ligament of the ankle joint is accompanied by rupture of the inferior tibio-fibular ligament with subluxation of the talus as shown by the wide joint space between it and the medial malleolus (Fig 1300) Although there is no fracture accurate replacement and immobilisation in plaster for at least ten weeks is essential (Fig 1301) Sometimes it is even wise to supplement the external support of a plaster cast with the internal fixation of a screw

FIG 1302

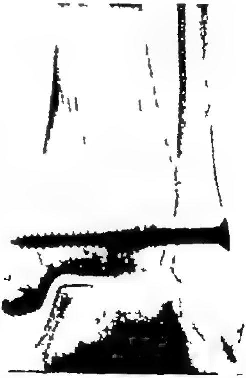


FIG 1303

Rupture of the medial ligament of the ankle and of the inferior tibio-fibular ligament not successfully reduced by simple manipulation and plaster (Fig 1302). It was treated by the internal fixation of a screw together with the support of a plaster cast (Fig 1303).

In avulsion fractures of the medial malleolus when a flap of periosteum is stripped from the tibia and interposed between the fractured surfaces the tissues must be hooked out and stitched back where they belong while at the same time the opportunity should often be taken of securing still firmer fixation by the insertion of a bone peg or screw If this is not done the fracture will probably fail to unite and a later bone-grafting operation may then be needed (Figs 1317 1318)

In fractures of the lateral malleolus it is sometimes wise to replace the fragments by open operation stitching the torn structures and perhaps fixing the fracture by an intramedullary nail (Fig 1319) There is a special indication for operative replacement when as a result of lateral rotation stress the lower end of the fibula is not only fractured but is locked behind the postero lateral ridge of the lower end of the tibia (Figs 1321 1322) [1 2]

In the same way when the inferior tibio-fibular ligament is torn from the tibia, it may avulse a fragment of bone It usually suffices to immobilise the joint in plaster for about two months but occasionally there is such tilting of the bone fragments as to need operative replacement (Fig 1320)

Such early operative treatment of joint injuries has been advocated vigorously by Gissane who with his team at the Birmingham Accident Hospital has made an important contribution in what they describe as traumatic anatomy with the thesis that prompt operation within a few hours of injury and accurate replacement of torn and separated soft tissues accelerates bone-healing and expedites full recovery

3 Malleolar fractures without displacement—The malleoli may be fractured not only by avulsion of the ligaments of the joint but also by the direct force of a thrust of the talus against the lateral malleolus medial malleolus posterior margin of the lower end of the tibia, or anterior margin of the tibia The position and shape of these fractures depends upon the direction of the violence If the foot is fixed to the ground and the patient in falling twists to the opposite side, there will be lateral rotation of the foot on the leg causing a spiral fracture of the lateral malleolus. If the foot is fixed and the patient falls to the same side there will be abduction stress causing a transverse fracture of the fibula at any level from the malleolus to the neck of the bone If the fall is in the opposite direction so that the foot is inverted on the leg there will be a fracture of the medial malleolus

The commonest of these injuries is a spiral fracture of the lateral malleolus from outward twisting of the foot The site of this fracture is surprisingly constant it always runs through the malleolus to just below the inferior tibio-fibular joint the ligaments of which are undisturbed Such spiral fractures of the lateral malleolus without displacement and without injury to the medial or inferior tibio fibular ligaments, are easy to treat It matters little whether the ankle is immobilised in plaster or treated by early movement

Similarly fractures of the lateral malleolus or of the shaft of the fibula from abduction force may occur without displacement and present no

Bosworth, D. M. "Fracture-dislocation of the Ankle with Fixed Displacement of the Fibula behind the Tibia" *J Bone Joint Surg* 1947 29, 130.
Harris R. I. *J Bone Joint Surg* 194[illegible] [illegible] 153.
Fleming, J. L. and Smith, H. O. "Fracture-dislocations of the Ankle with the Fibula fixed behind the Tibia." *J Bone Joint Surg* 1954 36-A, 556.

yet another at the end of the sixth week The patient should not be allowed to bear weight even in plaster until after six or eight weeks With sufficient care even these unstable injuries of the ankle with tibio-fibular diastasis can usually be treated successfully by conservative measures

Operative treatment—It is perhaps easier to use the internal fixation of a screw by which to supplement the external support of a plaster cast A strong thick screw is driven through the fibula to the opposite cortex of the tibia while an assistant grips the bones firmly together so that normal tightness of the tibio-fibular mortice is maintained (Figs 1302 1303) It is of course a serious mistake to think that such internal fixation can take the place of external support or that it can permit early weight bearing with safety The disasters that may arise from such attempts at early weight-bearing without external support are shown in Figure 1304 The

Fig 1304

Avulsion of the medial ligament (together with a fragment of bone from the malleolus) treated elsewhere by screw fixation without the external support of plaster and with immediate weight bearing Of course the screw broke and the diastasis recurred Note the lateral displacement of the talus from the medial malleolus (the tibio-fibular diastasis is concealed, as it so often is, because the shadows of the tibia and fibula overlap) The operation might just as well never have been done There should always be the support of a closely moulded and well fitting plaster for about ten weeks

tibio fibular diastasis had been fixed by a screw—but it was a very slender screw—and the patient was encouraged to walk on the fourth day without external support or protection Of course the screw broke and the displacement recurred there might just as well have been no operation at all Diastasis of the inferior tibio fibular joint with widening of the

FRACTURE OF THE LATERAL MALLEOLUS WITH INTERPOSITION OF THE PERONEAL TENDONS

FIG 1321

A rugged and healthy farmer aged 38 caught his left foot in a thresher and sustained a fracture of the ankle including injuries to the great toe and a fracture of the lateral malleolus, the malleolar fragment being displaced behind the lower end of the tibia. There was an open wound. It was quite clear that with this degree of displacement manipulative reduction might not succeed and at operation this was made quite evident by the fact that the peroneal tendons were interposed between the displaced malleolar fragment and the lower end of the tibia. It is the type of injury that has been made clear by R. I. Harris and D. Bosworth and later by J. L. Fleming and H. O. Smith who described locking of displacement of the lateral malleolar fragment behind the postero-lateral

ankle mortice must be treated with great respect No matter whether the displacement arises from disruption of ligaments alone, or as part of an abduction fracture-dislocation of the ankle joint there must always be safe external protection in plaster perhaps with the added internal fixation of a screw, and with deferment of weight bearing for about two months

INJURIES OF THE ANTERIOR CAPSULE AND LIGAMENTS OF THE ANKLE JOINT

The anterior capsule of the ankle joint is sometimes torn from its distal attachment of the neck of the talus but there is seldom complete avulsion The injury is often sustained by footballers who in kicking the ball usually take its weight on the dorsum of the foot so that there may be separation of the anterior capsule from the neck of the talus with resulting traumatic subperiosteal ossification (Fig 1305) Very seldom is there complete separation of the anterior capsule from the talus with resulting instability causing recurrent forward dislocation of the joint

Fig 1305

Avulsion of the anterior capsule of the ankle joint from the neck of the talus—an injury often sustained by footballers which causes subperiosteal ossification with the formation of a spur of bone above the neck of the talus as shown in this case

Recurrent forward dislocation of the ankle joint—Complete avulsion of the anterior capsule from the neck of the talus associated with momentary forward dislocation of the foot is so unusual that I have seen only two patients with recurrent forward dislocation (*Figs 1306 1310*) Every time these patients stepped out the tibia slid back on the body of the talus and then

FRACTURE OF THE LATERAL MALLEOLUS WITH INTERPOSITION OF THE PERONEAL TENDONS

FIG 1322

ridge of the lower end of the tibia. It can be corrected only by operative intervention as was done in this case at the Robert Jones and Agnes Hunt Orthopaedic Hospital. The peroneal tendons were hooked back so that the malleolar fragment could be replaced. The illustrations on the left page show the displacement of the malleolus before operation and on the right page the position immediately after operation. There was some delay in union but in the end the functional result was satisfactory. This case shows very clearly how displacement of the lateral malleolar fragment may be associated with interposition of the peroneal tendon, which makes it inevitable that correction should be by operative rather than manipulative means.

FIG. 1306

FIG. 1307

Recurrent forward dislocation of the ankle joint

Figures 1306-1307 are radiographs of the first case recorded of recurrent *forward* dislocation of the ankle joint.[1] The patient displaced the foot forward and backwards at the ankle whenever he put weight upon it. Radiographs show the displacement that occurred with every step (see also Figs. 1308-1310)

[1] Watson-Jones, R. "Recurrent Forward Dislocation of the Ankle Joint." Demonstration at the Combined Meeting of Orthopaedic Associations of the English-speaking World, London, July 19[illegible]. *J. Bone Joint Surg.* 19[illegible], 34-B, 519

CLASSIFICATION OF LIGAMENT-AVULSIONS, FRACTURES AND FRACTURE-DISLOCATIONS OF THE ANKLE JOINT

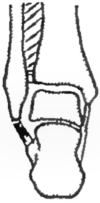


FIG. 1323

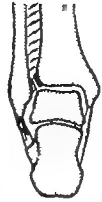


FIG. 1324

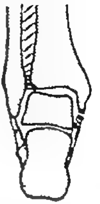


FIG. 1325

Avulsion with momentary dislocation, of the lateral ligament (Fig. 1323), inferior tibio-fibular ligament (Fig. 1324), and medial ligament of the ankle joint (Fig. 1325).

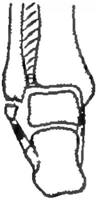


FIG. 1326

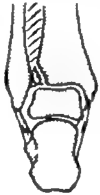


FIG. 1327

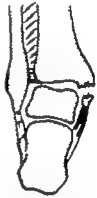


FIG. 1328

Avulsion together with a fragment of bone of the lateral ligament (Fig. 1326), inferior tibio-fibular ligament (Fig. 1327), and medial ligament of the ankle joint (Fig. 1328).

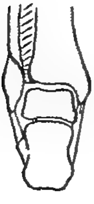


FIG. 1329

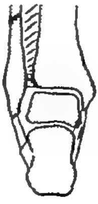


FIG. 1330

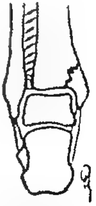


FIG. 1331

Isolated fracture without displacement of the lateral malleolus (Fig. 1329), lower shaft of the fibula (Fig. 1330), and medial malleolus (Fig. 1331).

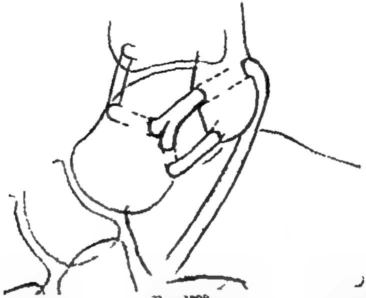


FIG. 1308

Operation devised for recurrent forward dislocation of the ankle joint. It is a simple modification of the tenodesis used for recurrent inward subluxation, but this time the tendon of peroneus longus was used. Half the tendon was passed back through the lateral malleolus in the ordinary way; the other half was passed through the neck of the talus to the medial side in order to provide an additional check to forward displacement of the tarsus.

FIG. 1309

FIG. 1310

Radiographs of the ankle joint of a patient with recurrent forward dislocation, before and after tenodes by the technique shown in Figure 1308. Note the drill hole in the talus and the lower end of the tib through which the two halves of the long peroneal tendon were united. The radiographs show th there is now perfect stability despite every passive movement or strain. (A few days ago I operate on this patient's other ankle because recurrent forward dislocation had developed on that side too, b this time without inward tilting. The tendon of peroneus longus was again used, but it was passe through the front of the calcaneum so that it provided a tenodesis on each side of the joint.) I mu acknowledge the help of my colleague Mr W. C. Robinson who studied and wrote up these cases for m

CLASSIFICATION OF LIGAMENT-AVULSIONS, FRACTURES AND FRACTURE-DISLOCATIONS OF THE ANKLE JOINT


Fig 1332


Fig 1333

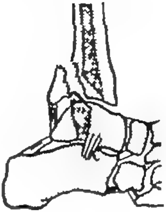


Fig 1334

Fracture-dislocation with lateral displacement—without tibio-fibular diastasis (Fig 1332), with tibio-fibular diastasis (Fig 1333) and with backward displacement (Fig 1334)

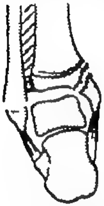


Fig 1335


Fig 1336

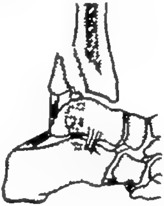


Fig 1337

Fracture-dislocation with medial displacement—in the adolescent, causing arrested growth of the tibial epiphysis (Fig. 1335) in the adult (Fig 1336); and with backward displacement (Fig 1337)

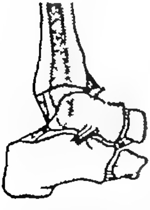


Fig. 1338

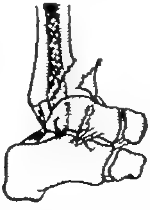


Fig 1339

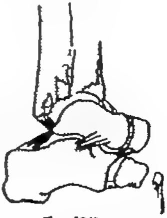


Fig 1340

Fracture-dislocation with forward displacement: with simple avulsion of the anterior capsule often with a fragment of bone (Fig 1338); with separation of a large anterior marginal fragment (Fig 1339) with comminution of the lower end of the tibia (Fig 1340)

slid forwards again as weight was taken off With the foot fixed firmly on the ground the leg bones could be displaced forwards or backwards on the tarsus at will There was severe disability and a reconstruction operation was performed similar to that used for inward dislocation of the ankle but using the tendon of peroneus longus rather than peroneus brevis in order to provide extra length for the ligament reconstruction needed After dissecting the tendon from its muscle fibres it was passed through a drill hole in the fibula and then divided into two parts one of which was threaded through the lateral part of the talus back to the fibula and the other through the neck of the talus to the medial side so that two strong ligamentous bands were provided one on each side of the joint to prevent forward displacement of the tarsus (Fig 1308) The symptoms were relieved and weight bearing radiographic studies showed that normal stability had been regained

RECURRENT DISLOCATION OF THE PERONEAL TENDONS

Three of the four causes of recurrent sprain and repeated giving way of the ankle joint have been discussed 1) the use of unsuitable shoes with high and worn heels 2) adhesions round the lateral malleolus and tarsus 3) recurrent subluxation of the talus at the ankle joint The fourth is recurrent dislocation of the peroneal tendons from the groove behind the lateral malleolus The depth of this groove and the mobility of the tendons vary considerably in normal individuals If the groove is shallow and the annular fibres forming its roof are lax, both tendons may slip over the margin of the bone on to the subcutaneous surface of the malleolus (Fig 1311) The displacement occurs when the foot is actively dorsiflexed and it is reduced when the foot is plantar flexed. Sharp jerking movement of the tendons from one position to the other causes pain weakness and giving way of the joint

Conservative treatment—At the time of the first displacement treatment by strapping encircling the limb immediately above the malleoli and kept in position for about six weeks may prevent recurrence of displacement of the tendons Raising the heel of the shoe by about a quarter of an inch may also help to keep them in position If the symptoms persist operative treatment is needed

Operative treatment—The peroneal groove of the lateral malleolus which should hold the tendons of peroneus brevis and peroneus longus in position may be deepened by a bone-transplanting operation Robert Kelly of Liverpool from whom I learned so much devised a procedure by which a thick flap of the subcutaneous surface of the lateral malleolus was swung back through at least one quarter of an inch so as to form a more prominent lip to the peroneal groove [1] He held the displaced "veneer of bone" in position by two screws In another case he used more complicated carpentry to avoid the necessity for screw fixation But the fact is that a thick osteoperiosteal flap cut from the surface of the lateral malleolus with an intact pedicle of periosteum and soft tissue swung back and held in position by one or two catgut sutures is all that is needed It is a simple operation it is the obvious device for the treatment of a rare condition One example is shown in Figures 1311 1312

[1] Kelly R. E. "An Operation for the Chronic Dislocation of the Peroneal Tendons" *Brit J Surg*, 1920, 7, 502

problem of treatment—but here there must be greater caution because when there is abduction stress the inferior tibio-fibular ligament is often torn and unless it is protected for two or three months there may be permanent disablement from the resulting laxity of the joint

Inversion injuries of the ankle joint cause fractures at the base of the medial malleolus If there is no associated rupture of the ligaments on the opposite side and if in children there is no crushing of the epiphysial line the management is again easy Simple protection with a crêpe bandage or in a walking plaster for six or eight weeks is all that is needed It must of course be understood that all these avulsions of ligaments, avulsion fractures of the malleoli and other malleolar fractures may be part of more serious fracture-dislocations which will be discussed in the next three groups

4. Fractures of the ankle joint with lateral or postero-lateral dislocation (Figs 1332 1334)—The commonest type of fracture-dislocation of the ankle joint is a spiral fracture of the lateral malleolus from rotational stress together with avulsion of the medial ligament perhaps with a fragment of bone and with lateral displacement of the joint Fracture-dislocation with lateral displacement may also arise from direct abduction stress when the fracture of the fibula is in the shaft of the bone usually in its lower third but sometimes higher in the shaft and even as high as the neck Such fractures of the fibula must of course be associated with rupture not only of the medial ligament of the ankle but also of the inferior tibio-fibular ligament which adds difficulty to the treatment In both types of fracture-dislocation—those sustained from lateral rotation stress and also those from abduction stress—there may be posterior as well as lateral dislocation because as the patient falls to the ground the foot may be driven backwards—or perhaps it is better to say that with the foot fixed on the ground the leg bones are driven forwards The resulting impact of the talus against the back of the lower end of the tibia may cause a posterior marginal fracture

5 Fractures of the ankle joint with medial or postero-medial dislocation (Figs 1335-1337)—The opposite injury of inversion of the ankle joint causes fracture of the medial malleolus which lies in a more vertical plane than the transverse fractures produced by avulsion of the lateral ligament In growing children the injury is often associated with crushing of the inner part of the epiphysis at the lower end of the tibia with consequent arrest of growth. In adults the medial malleolus is shorn off in a relatively vertical plane the lateral malleolus is avulsed the foot is displaced inwards and unfortunately there is often comminution of the lateral part of the lower tibial articular surface As with fracture-dislocations from lateral rotation and eversion injury so with these fracture-dislocations from inversion injury the foot may be driven backwards at the moment of injury so that there is posterior as well as medial dislocation

6 Fractures of the ankle with forward dislocation (Figs 1338-1340)—Forward dislocation of the ankle joint occurs far less commonly than backward dislocation We have seen that the anterior ligaments and capsule may be avulsed from the neck of the talus as a result of plantar flexion strain as for example in those who play football and take the weight of the ball on the dorsal surface of the plantar flexed foot This avulsion of the anterior

capsule sometimes gives rise to subperiosteal ossification Very occasionally when such injuries are not suitably immobilised at the time of the first injury, recurrent forward dislocation develops Sometimes vertical compression injuries cause separation of an anterior marginal fragment from the front of the lower end of the tibia with forward displacement of the tarsus [1] If the violence of vertical compression is still more direct there may also be comminution of the lower end of the tibia

TREATMENT OF FRACTURES AND FRACTURE-DISLOCATIONS OF THE ANKLE JOINT

Fractures of the lateral malleolus without displacement—This injury usually occurs from lateral rotation stress It is a spiral fracture at the level of the inferior tibio fibular joint but without injury to the ligaments of the joint and without displacement It gets well regardless of treatment Some surgeons advise local infiltration with procaine, others advise protection in a weight bearing plaster for a few weeks and many suggest no more than the support of a crêpe bandage If we can be quite sure that the fracture is in fact no more than an isolated injury from lateral rotation without displacement and without injury to the medial ligament of the joint it matters little what is done Recovery will be complete within a few weeks

Fracture of the medial malleolus without displacement—Fractures of the medial malleolus may arise from avulsion of the medial ligament, when the fracture line is in the transverse plane or from forcible inversion of the foot when the plane of fracture is more vertical. If there is no displacement it can be treated safely by protection in plaster for a few weeks or by the simple support of a crêpe bandage But the surgeon must always be alert as to the possibility of interposition of a periosteal flap between the fractured surfaces which prevents bone union The interposed soft tissues should then be hooked out the malleolar fragment being replaced in accurate position—perhaps with the internal fixation of a screw In the occasional case where this has not been done in the first few days after injury so that non union has developed the bone surfaces should be refreshened and drilled before a screw is introduced It may even be wise to inlay a bone graft

Avulsion of fragments of the tibia by the inferior tibio fibular ligament—If these avulsed fragments are not replaced accurately after simple manipulative correction of the displacement of the joint they should be replaced through a short incision with simple suture of the periosteal tissues

Fractures of the ankle joint with lateral or postero lateral dislocation—Simple manipulative reduction nearly always succeeds Under general anaesthesia the foot must be pressed strongly inwards so that the talus is restored in accurate relationship with the tibio fibular *mortice* and if there is also posterior dislocation the foot must be manipulated strongly forwards as well as inwards It is usually *impossible* to over reduce the displacement by manual pressure because the malleolar fragments lock against

[1] Lees E. "Marginal Articular Fractures of Tibia—Review of Recorded Cases," *Ann Bel. Chir.*, 1933, II 337

Fig 1299

Injury of the ankle joint in a child with postero-medial displacement of the lower tibial epiphysis The direction of the displacement in such injuries corresponds exactly with the fractures of adults—lateral, postero-lateral, medial, postero-medial, and so on A large triangular metaphysial fragment is broken off and displaced with the epiphysis

Fig 1300

In such injuries of children the line of fracture is not *through* the epiphysial line but *adjacent* to it There is therefore no arrest of later growth The only treatment needed is to correct the displacement by manipulation, exactly a would be done in the adult

each other With the limb hanging over the end of a table an unpadded plaster is applied from the toes to just below the knee with the foot at right angles and neutral to inversion and eversion While the plaster is setting the surgeon should again use both his hands one over the medial side of the shaft of the tibia and the other over the lateral side of the foot pushing it strongly inwards It is futile to try to reduce the displacement just by inverting the foot which expends all the energy on the mid tarsal joint and does little or nothing to the ankle joint The replacement must be secured by direct pressure over the lateral malleolus and the lateral side of the foot.

Fig 1341

Fig 134?

After manipulative reduction an assistant holds the foot in dorsiflexion while plaster is rapidly applied (Fig 1341) During this stage or while the plaster is setting, backward dislocation may recur. The foot must be pulled strongly forwards and inwards by the surgeon's hands, dorsiflexed with the knee and held while the plaster sets (Fig 134)

This pressure should be sustained while the plaster is being applied (Figs 1341 1342) The completeness of reduction must of course be confirmed by radiographic examination The accuracy of replacement of the talus within the tibio fibular mortice is most important For example in Figures 1343-1345 there was obviously imperfect correction of the lateral subluxation and another manipulation under anaesthesia was needed before normal relationship of the talus within the tibio-fibular mortice was restored

If there is not only lateral but also backward displacement of the tarsal bones on the tibia this must be corrected with equal care Such displacement with a posterior marginal fracture of the lower end of the tibia is shown in Figure 1340 and its correction by manipulation is seen in Figure 134? There must be special care in securing accurate replacement of the talus

prompt stapling of the lateral part of the lower tibial epiphysis and of the fibular epiphysis in order to prevent deformity The fact is however that

Fig 1361 Fig 1362

Injury of the ankle joint in a child from inversion stress. Even in the earlier x ray (Fig 1361) there is suspicion of damage to the medial part of the lower tibial epiphysial line. This is confirmed by the obvious arrest of growth shown in the x rays twelve months later (Fig 1362)

Fig 1363

Varus deformity of the ankle from arrested growth of the medial part of the lower tibial epiphysis from an adduction fracture sustained in childhood.

it is never possible to be certain as to the extent to which these injuries will arrest growth and it is far better to pursue simple conservative measures

Fig 1343

Fracture of the ankle with lateral dislocation. The fracture of the lateral malleolus is spiral in shape in the typical position, proving that the injury was sustained from lateral rotation stress.

Fig 1344

Fig 1345

After attempted manipulative reduction, radiographs show clearly that the replacement is imperfect (Fig 1344) the talus is still displaced laterally by at least one-quarter of an inch. Another manipulation was needed, after which the talus was replaced correctly in the mortice (Fig 1345).

for the first few years and even until growth has ceased Only after that should the inversion deformity of the foot be corrected by osteotomy This is performed through a lateral incision A wedge of bone base outwards is resected from the fibula just above the malleolus and from the tibia at a corresponding level immediately above the ankle joint The deformity is then corrected and the limb is held in plaster for about three months

MAL-UNITED FRACTURE-DISLOCATIONS OF THE ANKLE JOINT

When fractures of the ankle with lateral postero-lateral medial or forward dislocation are left with displacement uncorrected it may often be possible even after several weeks to correct the displacement by manipulation Nevertheless it should be recognised that if the displacement is not corrected within the first ten or fourteen days the opportunity has usually been lost There cannot be a perfect functional result unless the talus is replaced accurately in the tibio-fibular mortice and the fragments which have been separated from the tibio fibular articular surfaces are restored in perfect position Otherwise traumatic arthritis will arise The disability is of course made worse by resulting valgus or varus deformities of the foot which increase the strain (Fig 1364) At the same time it must be recognised that simple correction of these deformities by osteotomy will not relieve the disability or prevent the development of osteo-arthritis if irregularities and misfits of the articulating bones still remain Arthrodesis is needed.[1 5] Fortunately the penalty of arthrodesis, with its restriction of movement applies far less to the ankle than to most other joints because the subtalar and mid tarsal joints contribute so great a range The fact is that these joints alone provide such good plantar flexion and dorsiflexion movement of the foot on the leg that after sound arthrodesis of the ankle joint it is often quite difficult to know that movement is restricted at all The patient walks without a limp runs jumps and pursues all recreations and occupations with a negligible disability It is wrong therefore to explain an arthrodesis of the ankle to a patient as a stiffening procedure Recognising the stiffness that is already present he imagines something worse and quite probably will refuse

FIG 1364

Mal united abduction fracture-dislocation of ankle. The foot is in valgus and body weight passes to its inner side.

Henderson, M. & Stuck, W "Fractures of Ankle" (summary of literature) *J Bone Joint Surg* 1932, 14, 6…
Padovani, M. P "Treatment Mal-united Fractures Ankle" *Rev d'Orthop* 1935, 22, 441
Speed, J S and Boyd, H S "Mal-united Fractures about Ankle" *J Bone Joint Surg* 1936, 18, 270
Kimberley A G "Mal-united Fractures, Ankle Joint, treated by Arthrodesis" *Surg Gyn Obst* 1936 62, 79.
Couvelaire R., Baumann, J and Delmott P "Technique and Indications Complete Tibio-tarsal Resection for Traumatic Lesions Ankle Joint" *J Chir*, Paris 1938 51 334

FIG. 1346

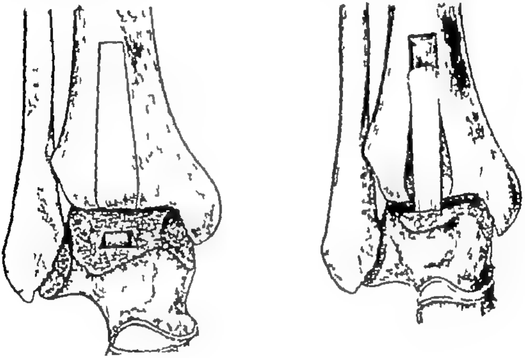
Backward displacement of the talus with fracture of the posterior margin of the tibia and of the lateral malleolus. Note that the displacement cannot be seen in the antero-posterior view

FIG. 134[illegible]

After manipulative reduction and plaster the dislocation is completely reduced. The articular surface of the talus is exactly parallel with that of the tibia. The fracture of the posterior margin of the tibia involves only a small part of the articular surface

the operation It should be described as an operation which will not alter the range of movement of the foot but will relieve the pain and allow him to walk and run without disability

The position in which the ankle joint is fixed is of great importance Tilting into valgus or varus must be corrected completely because otherwise the patient will walk on the inner or outer border of the foot where painful callosities will develop and there will be constant strain of the tarsal joints. The foot must not be fixed in the inverted position This is not a position of strength—it is a deformity which causes disability quite similar to that of the opposite deformity of fixed eversion The ankle should be fixed in



Look at Figure 1348. Here was a fracture-dislocation of the ankle joint from rotation-abduction stress with lateral displacement and posterior displacement which had been manipulated and immobilised in plaster, it was thought to have been replaced. Clearly however the talus is not correctly aligned with the tibia. The curve of the upper surface of the talus conforms with that of the displaced posterior marginal fragment of the tibia but it is not parallel with the main tibial articular surface in front. The foot is still displaced backwards. If such displacement is left uncorrected degenerative osteo arthritis will certainly develop. There is, of course no difficulty in preventing this by completing the reduction—that is to say by pulling the foot strongly forwards during the reduction and holding it in this position while the plaster cast is applied.

FIG. 1348

Does this post reduction radiograph show *satisfactory correction of backward disloca tion of the ankle joint?* (See text.)

Fractures of the ankle joint with lateral or postero-lateral dislocation and with diastasis of the inferior tibio-fibular joint—Special care must be taken when fracture-dislocations of the ankle joint with lateral displacement are associated not with spiral fractures of the malleolus from rotation stress but with transverse or oblique fractures of the shaft of the fibula from abduction stress. The fracture of the fibula may be high in the shaft—even as high as the neck of the bone. These injuries demand careful treatment because when the inferior tibio-fibular ligament is ruptured there is a marked tendency to redisplacement with persistent separation of the bones at the inferior tibio fibular joint and a loose and unstable ankle joint which in later years causes osteo-arthritis. It is sometimes said that these lateral abduction fracture-dislocations with avulsion of the inferior tibio-fibular ligaments cannot be treated successfully without internal fixation—but this exaggerates the difficulty. If care is taken in moulding the plaster by the

Fig 1367

Unreduced vertical compression fracture of tibia with forward displacement of the talus. The joint was almost completely stiff and very painful

Fig 1368

After arthrodesis of the ankle joint the pain was relieved and such free movement developed at the mid tarsal subtaloid joints that it was difficult to believe that the ankle joint itself was not moving This is very often so, especially in all younger patients.

pressure of the palms of the surgeon's hands, and if new plaster casts are applied as soon as there is the first sign of looseness or slackness, always with deferment of weight-bearing for eight or ten weeks, conservative treatment usually succeeds. On the other hand it may be easier to supplement the external support of plaster by the internal fixation of a screw (Figs 1349-1350). But let it be recognised clearly that the insertion of a screw through the fibula into the tibia can never be expected to be more than a supplement to external support. Such screws cannot by themselves withstand all the strains, and certainly they cannot provide a sufficient fixation to permit weight bearing within a few days. After all, what does it matter that an

FIG. 1349

FIG. 1350

Typical fracture-dislocation of the ankle joint with lateral displacement from eversion stress as proved by the oblique fracture high in the shaft of the fibula and the clear evidence of avulsion not only of the medial ligament of the ankle joint but also of the inferior tibio-fibular ligament (Fig 1349). It was decided to supplement the external support of a closely fitting plaster cast with the internal fixation of a screw between the fibula and the tibia (Fig 1350). But let it be noted very clearly that the screw was never intended to do more than supplement the support of the plaster casts which were always closely moulded and were kept in position for ten weeks without any weight bearing being permitted before that time. To see the importance of this observation look back to Figure 1304.

ankle joint is in plaster for a few weeks? What gain is made by bearing weight after a few days instead of after a few weeks when what really matters is the soundness of the joint for another twenty or more years.

Fractures of the ankle joint with medial or postero-medial dislocation.—These fracture-dislocations are caused by adduction violence; they are the *mirror image of the more common abduction fracture-dislocations*. The principles of treatment are of course the same. Displacement of the tarsal bones and of the talus in relation to the tibio-fibular mortice must be corrected by strong pressure applied over the medial malleolus and the medial side of the foot. Once again it is satisfying to know that over-reduction is almost impossible—the bones lock in their correctly reduced position if strong pressure is applied. Surgeons sometimes trust in a fallacy that because

FIG 1369

Severe fracture-dislocation of the ankle joint which was first reduced by manipulation and immobilised in plaster but in which the injury to the joint surfaces was so grave that traumatic arthritis soon developed

FIG 1370

Two years later the ankle joint was arthrodesed by the method described in the text of denuding the ankle joint surfaces of cartilage and screwing the lower part of the fibula to the lateral side of the tibia and talus To-day after several years, you could not distinguish this patient from a normal man The range of movement of the foot and ankle appears to be almost normal and he walks without a limp.

the everted position of the foot is one of weakness the inverted position must be one of strength Thus in treating fracture dislocations of the ankle with inward displacement they hesitate to push the heel strongly enough outwards The fact is of course that a tilted position of the talus causes a similar incapacity whether the tilt is outwards or inwards pain and disability persist and osteo arthritis develops The inverted position of the foot is not strong—the only position of strength is the normal and neutral position in which the talus lies in accurate relationship with the tibio-fibular mortice This is attained in fracture-dislocations of the ankle joint with inward displacement only by very strong outward pressure on the inner side of the heel Plaster is then applied and while it is setting the pressure should again be maintained (Fig 1352) The joint is immobilised

Fig 1331
Fractures of the ankle with medial dislocation

Fig 1352
While the plaster is setting the foot must be pushed outwards The displacement will not be over reduced even with strong pressure

for about ten weeks but usually a new unpadded plaster is applied afte the third week and weight bearing in plaster may then be permitted Unfortunately as in the example seen in Figure 1351 these fractures of th ankle joint with medial displacement are often associated with crushing o the lower end of the tibia In children this may cause injury to the lowe tibial epiphysial line on its medial side with premature arrest of growth an progressive deformity and in adults the damage to the joint surfaces ma be so great that early arthrodesis is needed

Fractures of the ankle joint with forward displacement—Forwar displacement of the foot on the tibia from violent plantar flexion strain have already been discussed (Fig 1306) Falls from a height on to the heel with vertical compression may cause forward dislocation of the foot wit separation of an anterior marginal fragment from the tibia and sometime with comminution of the *articular surface* It must be remembered tha

implanted into a socket in the talus (Figs 1365 1368) The success of the operation depended not only on completely denuding the cartilage of the articular surfaces and freshening the bones but on very accurate carpentry by which the graft fitted into its socket in the talus and maintained a sufficient degree of internal fixation of the joint It was not an easy operation, and no doubt there were many failures

Arthrodesis of the ankle by screwing the fibula to the tibia and talus—An easier and more certain technique has now been developed[1] The joint is exposed from the lateral side the lower four inches of the fibula with its malleolus being removed The articular cartilage between the tibia and talus is then excised and the surfaces are thoroughly refreshened At the same time bone is removed in such a way as to correct such valgus or varus deformity as there may be A bed is prepared on the lateral side of the lower end of the tibia and talus to which is screwed the refreshened fragment of the fibula The fixation secured in this way is so sound that after simple protection of the limb in plaster for about twelve weeks firm arthrodesis of the joint is assured (Figs 1369 1370)

OPEN FRACTURE-DISLOCATIONS OF THE ANKLE JOINT

Dislocations and fracture-dislocations of the ankle joint are frequently compound because the malleoli of the tibia and fibula are situated immediately beneath the skin If there is severe deformity with gross displacement of the foot to one side the skin over the opposite side of the ankle may be split and the flaps are buttonholed round the lower end of the leg bones leaving the articular surface of the joint exposed in the wound The soft-tissue injury may be very severe but nevertheless the injury is compound from within The wound occurs because the tibia or fibula burst outwards and not by reason of a direct crushing injury which devitalises tissues and drives foreign bodies into deep recesses The prognosis is therefore excellent By suitable operative treatment first intention healing is usually possible

Open adduction fracture-dislocation of the ankle joint—A motor-cyclist aged thirty five was crushed between a lorry and a wall He sustained closed fractures of the right tibia and fibula, an open fracture of the shaft of the right femur and an open adduction fracture-dislocation of the left ankle with stripping of soft tissues from the whole of the side of the leg (Figs 1371 1374) The ankle injury was of the type just described the rupture of skin fasciæ and muscles being due to bursting out of the tibia In this patient the skin flaps were widely undermined and the blood supply was precarious Immediate operation was performed First intention healing was achieved except for a small patch of skin necrosis due to ischæmia. The fracture-dislocation was immobilised in plaster for ten weeks the fracture of the right tibia also being immobilised in plaster and the fracture of the femur in splints with skeletal traction Weight bearing was resumed after thirteen weeks The left ankle regained three-quarters of the normal range of movement and the patient went back to his full work in eight months

[1] Adams, J C. "Arthrodesis of the Ankle Joint." *J Bone Joint S rg* 1948 30-B, 506.

FIG. 1333

Vertical compression fracture of tibia with comminution, displacement of a large anterior marginal fragment and forward dislocation of the talus.

FIG. 1334

Same case as shown in Figure 1333, after treatment. The patient also fractured the calcaneum of the opposite foot but is now back at full work on ladders as a window cleaner. The foot must be plantar flexed at the ankle—not dorsiflexed.

OPEN FRACTURE-DISLOCATION OF THE ANKLE JOINT WITH SEVERE DAMAGE TO THE SOFT TISSUES

Fig. 1371

Fig. 1372

This patient sustained a very severe inversion injury of the ankle joint with fractures of the malleoli, complete inward dislocation of the foot, and extensive laceration of all soft tissues on the outer side of the joint as well as splitting of the skin over most of the side of the leg.

FIG 1355

Forward dislocation of the ankle joint with anterior marginal fracture of the tibia (and fractures of the medial malleolus and lateral margin of the tibia)

FIG 1356

Interposed periosteal flaps were withdrawn, the dislocation was reduced and the detached fragments were fixed by vitallium screws (see Figures 1357 1358)

FIG 1357

FIG 1358

Forward dislocation of the ankle joint with marginal fractures and interposition of periosteal flaps during operative reduction and internal fixation with screws. (Same case as shown in Figures 1355-1356.)

OPEN FRACTURE-DISLOCATION OF THE ANKLE JOINT WITH SEVERE DAMAGE TO THE SOFT TISSUES

FIG 1373

FIG 1374

The injury shown in Figures 1373, 1374 was from bursting of the bones outwards—not from a force driving inwards—so that there was little contamination and the prognosis was excellent The wound was excised; the displacement was reduced by manipulation; and a perfect result was achieved. (Treated by P B Moroney my assistant in Liverpool)

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such falls may also cause vertical compression fractures of the spine and fractures of the calcaneum and special care must be taken to look for such injuries in fracture-dislocations of the ankle joint with forward displacement The separation of a large anterior marginal fragment which may carry with it as much as one third or half of the articular surface will obviously distort the joint and give rise to later osteo-arthritis unless it is accurately reduced. Sometimes it is possible to correct the displacement by simple manipulation and immobilisation in plaster (Figs 1353 1354) If however such manipulations fail to restore a perfect contour to the tibial articular surface *there should be no hesitation in performing an open operative reduction*, replacing the anterior marginal fragment accurately and taking the opportunity to fix it with a screw (Figs 1355-1358) Sometimes of course the comminution of the tibial articular surface and destruction of the joint is so great that arthrodesis is inevitable

FRACTURES AND EPIPHYSIAL DISPLACEMENTS OF THE ANKLE JOINT IN CHILDREN

Injuries of the ankle joint in children with epiphysial separation—The injuries to the ankle that we have discussed with postero lateral and postero medial displacement in adults may also occur in children where the line of injury runs adjacent to the lower tibial epiphysis As with all other epiphysial injuries there is separation of a metaphysial fragment A typical example is shown in Figure 1359 The lower tibial epiphysis together with a large metaphysial fragment is displaced backwards This injury arises from rotational stress and not from compression force It is to be recognised as a fracture adjacent to the epiphysial line and not as an injury crushing the epiphysis In such injuries if the displacement is corrected by *manipulation with immobilisation in plaster* recovery will be quite complete There will be no interruption of epiphysial growth (Fig 1360). All these fractures adjacent to the lower tibial epiphysial line are exactly comparable to fracture-dislocations of the ankle joint in adults There may be displacement outwards backwards inwards or forwards and the simple conservative methods of manipulative reduction and immobilisation in plaster are indicated

Injuries of the ankle joint in children with epiphysial crushing—*Inversion* injuries of the ankle joint in children are much more serious because they so often cause crushing of the inner part of the lower tibial epiphysis The talus is driven against the inner side of the tibio fibular mortice in such a way that it crushes the medial part of the lower tibial epiphysis In consequence growth is arrested on the medial side whereas it continues on the lateral side of the lower end of the tibia and in the fibula As years go by this causes severe inversion deformity of the foot (Figs 1361 1363) The deformity increases steadily until growth ceases at the age of about twenty

At the time of injury the joint should of course, be protected in a plaster cast for two or three months Even although the surgeon may then suspect that the epiphysis has been crushed and that growth might be arrested he should not be hasty in planning operative intervention It has been suggested that whenever epiphysial crushing is sustained there should be

OPEN FRACTURE-DISLOCATION OF THE ANKLE JOINT WITH SEVERE DAMAGE TO THE SOFT TISSUES

FIG 1371

FIG 1372

This patient sustained a very severe inversion injury of the ankle joint with fractures of the malleoli, complete inward dislocation of the foot, and extensive laceration of all soft tissues on the outer side of the joint as well as splitting of the skin over most of the side of the leg

OPEN FRACTURE-DISLOCATION OF THE ANKLE JOINT WITH SEVERE DAMAGE TO THE SOFT TISSUES

FIG 1373

FIG 1374

The injury shown in Figures 1371 1372 was from bursting of the bones outwards—not from a force driving inwards—so that there was little contamination and the prognosis was excellent The wound was excised; the displacement was reduced by manipulation; and a perfect result was achieved. (Treated by P H Moroney my assistant in Liverpool)

Fig 1305

Fracture of the calcaneum with displacement, adjacent to but not entering the subtalar joint. This is the basic line of fracture of the calcaneum from the postero-medial to the antero-lateral part but not involving the joint surface Simple manipulative replacement is all that is needed.

Fig 1306

Fracture of the calcaneum with displacement of the lateral part of the subtalar joint. The large postero-lateral fragment of the calcaneum is separated from the smaller antero-medial fragment—operative replacement is indicated.

Fig 1307

Fracture of the calcaneum with central crushing of the whole subtalar joint. In this type of fracture the damage to the joint is so extensive that *primary* arthrodesis is often needed.

FIG 1375

Same case as shown in Figure 1377 The injury is a severe abduction fracture-dislocation with avulsion of the medial malleolus tibio-fibular diastasis and fractures of the fibula.

FIG. 1376

Radiographs through plaster after excision of the wound and reduction of the fracture-dislocation

SOURCES OF DISABILITY AFTER FRACTURES OF THE CALCANEUM

Before discussing treatment it is wise to consider the disabilities that may arise from this serious group of fractures[1,5]. They can be listed under the headings (1) thickening of bone with undue prominence beneath the tuberosity and resulting pain under the heel from the impact of weight bearing (2) lateral thickening of the bone which in itself is ugly and causes distortion in the shape of shoes, and may cause pain from impingement against the lateral malleolus (3) upward displacement of the tuberosity which is the equivalent of lengthening the tendo Achillis and causes such loss of power as to make it difficult to stand on tip-toe or to walk with a normal heel and toe spring (4) valgus deformity of the heel causing secondary strain on the other tarsal joints with traumatic flat foot (5) arthritis of the subtalar or mid tarsal joints into which the fracture extends and where there is often grave damage of the articular surfaces.

Thickening of the calcaneum—Thickening of the heel results from vertical crushing and lateral spreading with separation of an antero-medial and a larger postero-lateral fragment. The various types of fracture causing this thickening have already been outlined. The displacement can usually be corrected by manipulative treatment at the time of injury. In later stages, when there is mal union, it may sometimes be wise to remove the excess of bone from the lateral part of the body of the calcaneum. If there is thickening with pain under the heel from the impact of weight bearing the heel of the shoe should be hollowed out the excavation being filled with sorbo-rubber.

Upward displacement of the tuberosity with laxity of the tendo Achillis—Upward displacement of the tuberosity which in its effect amounts to lengthening of the tendo Achillis with loss of power in the calf group of muscles explains why it is often difficult to stand on tip-toe after this fracture and why it is difficult to walk with a normal spring. This too can usually be corrected in the early stages. If it has not been so corrected it is fortunate that by retraction of the calf muscles considerable compensation is often gained even when in earlier days there may have been marked excess of passive dorsiflexion and loss of power of active plantar-flexion. The patient gradually learns to stand on tip-toe so that the gait is much improved.

Valgus deformity of the heel—Valgus deformity of the heel, especially when a large postero-lateral fragment of the body of the calcaneum is displaced outwards is associated not only with traumatic arthritis of the subtalar joint but often with secondary arthritis of the other tarsal joints. Not uncommonly traumatic arthritis of the injured joints causes spasm of the peroneal muscles with spasmodic flat foot thus increasing the valgus deformity (Fig 1402). This is relieved only when the joint becomes ankylosed or when it is deliberately arthrodesed (Fig 1403).

Injury to the subtalar joint surface—Traumatic arthritis from direct injury to the subtalar and calcaneo-cuboid joints is the most serious disability in these injuries. The comminution of bone and destruction of articular

Rothberg, A. S. "Avulsion Fracture of Os Calcis." *J Bone Joint Surg.*, 1939, 21, 218.
Böhler, L. "Treatment of Fractures." Bristol: John Wright and Sons Ltd., 4th ed., 1935, 478.
Schofield, R. O. "Fractures of Os Calcis" (fifty-two cases sustained at Boulder Dam and reduced by Böhler technique; incapacity periods from six to twelve months; average permanent loss of function [illegible] per cent). *J Bone Joint Surg.*, 1936, 18, 566.
Jackle, R. F. and Clark, A. G. "Fractures of Os Calcis" (forty-three cases sustained at Boulder Dam, reduced and final disabilities assessed). *S rg Gyn. Obstet* 64, 663.
Goff, C. W. "Fresh Fractures of Os Calcis." *Arch. Surg* 1935, 30, 744.

Open abduction fracture-dislocation of the ankle joint—A school teacher aged fifty-eight slipped on the stairs in her own home The accident seemed trivial but the power of body weight is such that a severe fracture-dislocation was sustained (Figs 1375-1377) Within two hours of injury the skin margins were excised loose fringes of avascular tissue were removed, and the

FIG 1377
Compound fracture-dislocation of ankle sustained by a patient aged fifty-eight years, who tripped on a stair

hæmorrhage was arrested by the pressure of artery forceps The dislocation was reduced a padded plaster applied and the limb elevated. Check radiographs showed satisfactory reduction The plaster was removed at the tenth week, an elastic supporting bandage was used for two weeks and after fifteen weeks the patient returned to full duties

surfaces may be so complete that fibrous ankylosis develops spontaneously It is probably for this reason that success is often gained by treatment in which no attempt is made to reduce the displacement The simple support of a crêpe bandage is relied upon It would seem, however, that if damage to the joint is so serious that ankylosis is the best result to be expected, it should be promoted by surgical intervention , whereas if this is not so it would be better to reduce the thickening correct the upward displacement of the tuberosity and replace the subtalar joint surfaces

Principles of treatment—The treatment of fractures not involving the subtalar joint presents no special problem. For fractures which do involve the joint we must consider four plans of treatment 1) simple rest for a few weeks with the support of a crêpe bandage 2) correction of displacement by skeletal pin traction on a Böhler frame or by means of a pin through the back of the tuberosity 3) operative reduction with restoration of the subtalar joint surfaces by elevating the postero-lateral fragment and filling the bone defect by cancellous grafts 4) primary arthrodesis of the subtalar joint and perhaps also of the mid tarsal joint

TREATMENT OF FRACTURES OF THE CALCANEUM

Treatment of fractures not involving the subtalar joint—The treatment of fractures not involving the subtalar joint is relatively simple When there is a *vertical fracture of the tuberosity* manipulation is seldom needed A walking plaster should be applied for about six weeks with a crêpe bandage for some weeks thereafter In occasional cases when there is more severe displacement of the medial process of the tuberosity which might cause spur formation and resulting local tenderness, it should be corrected by compression between the surgeon s two hands before the plaster is applied It may be

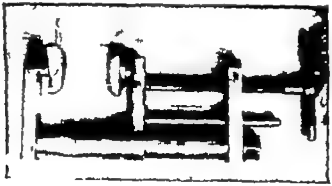

FIG. 1308
Bohler s clamp for lateral compression of calcaneum

wise to use the still stronger compression of a Böhler s clamp (Fig 1308) In *horizontal fractures of the tuberosity* or beak fractures as they are sometimes known the upward tilting should be corrected by plantar flexing the foot and applying direct pressure over the displaced fragment A walking plaster should be applied with the ankle joint in a few degrees of plantar flexion The plaster may be removed after about six weeks recurrent œdema being prevented by the support of a crêpe bandage and active exercise In the

the talus between the posterior and anterior subtalar joint surfaces and the anterior end articulating with the cuboid

The shape of the calcaneum is such that there is normally an angle between the axis of the tuberosity and the body of the bone which is known as the tuber joint angle or the salient angle (see inset Figure 1379) This is the angle between a line projected back from the subtalar articular surfaces and the line of the upper margin of the tuberosity of the bone In a normal calcaneum it measures about 40 degrees If from a compression fracture the tuberosity is displaced upwards or the articular surface is displaced downwards the angle may be reduced to 20 or 10 degrees It may be obliterated altogether or it may even be represented by a negative angle This angle should be *estimated in determining the degree of upward*

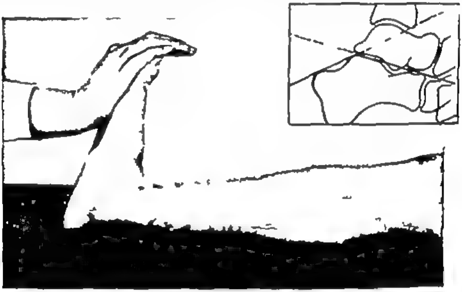

FIG 1379

In all severe fractures of the calcaneum the tuberosity is displaced upwards This may amount to as much as one inch, or even more and if it is left uncorrected the functional effect is just the same as if the tendo Achillis had been lengthened by one inch or more This is displayed clinically by the excessive passive dorsiflexion of the foot as shown in this patient It explains the difficulty of standing on tip-toe or walking with a normal heel to toe spring The normal tuber joint angle which is lost in compression fractures, is shown in the inset

displacement of the tuberosity whether from fractures involving the joint or from fractures escaping the joint surfaces Such upward displacement of the tuberosity and therefore of the insertion of the tendo Achillis causes difficulty in standing on tip-toe and impairment of the normal heel and toe movement of walking which depends upon full power of the calf group of muscles The upward displacement may amount to as much as one inch. In its functional result this is just the same as if the tendo Achillis had been lengthened by one inch In consequence there is excessive passive dorsiflexion of the ankle joint as shown in Figure 1379

Broadening of the heel which should be recognised from clinical examination and is seen in radiographs taken in the axial projection may in itself cause disability especially when it is associated with valgus displacement of the foot There may even be pain from impingement of the tarsal bones against the lateral malleolus

very rare case of *avulsion fracture of the tuberosity* arising from pull of the tendo Achillis so that an oval shaped fragment of bone is torn from the back of the bone and is completely detached and displaced upwards the fragment should be replaced through a lateral incision over the heel and held in position by one or two catgut sutures usually just through the periosteum and soft tissues but if necessary through oblique drill holes in the bone *Fractures of the sustentaculum tali* when isolated and not associated with other fractures of the calcaneum need only be immobilised in a walking plaster for six weeks unless by chance there is slight lateral displacement which should be corrected by manual pressure before the plaster is applied In isolated *fractures of the anterior end of the bone* displacement is usually unimportant The foot should be protected in a below knee walking plaster for six weeks after which time active exercise restores full movement and minimises gravitational oedema Only when large fragments of the calcaneum are separated and tilted with more severe damage to the calcaneal cuboid joint is operative intervention needed. In these rare cases it is often best to perform an arthrodesis

Treatment of fractures involving the subtalar joint—1) *Treatment by simple bed rest with a crêpe bandage and early mobilisation*—No attempt is made to correct the displacement The patient is put to bed for a few days and a crêpe bandage is applied from the toes to below the knee Weight-bearing is encouraged as soon as possible The patient stands and walks within a week or two If the original injury caused such destruction of the subtalar and mid tarsal joints as to cause fibrous ankylosis he will probably get back to ordinary activities within about six months with of course stiffness of the tarsal joints but without too much pain There may be lack of heel and toe spring because the tuber of the calcaneum is displaced upwards so that there is relative lengthening of the tendo Achillis. There may also be thickening of the heel and valgus deformity with ugly displacement of shoes But even with such limitations the patient will often be capable of doing a full day s work Indeed after careful clinical study and statistical analysis Essex Lopresti concluded that it was even harmful to immobilise the foot in plaster [1] For all patients over the age of fifty years with fractures of the calcaneum he advised early exercise without plaster fixation Norman Roberts [2] believed that this was the best routine treatment for all crush fractures of the calcaneum From a follow up study he concluded that patients whose fractures had been reduced by skeletal traction and immobilisation in plaster seldom got back to work within twelve months whereas the disability period was halved to only six months if they were treated by simple bed rest for a week or two with early weight bearing and only the support of a bandage He said that three quarters of the patients so treated went back to full work. Certainly this proposal of treatment by simple bed rest and early weight bearing must be considered seriously fatalistic as it may seem to be It is of course true that many of the results of attempted reduction by skeletal traction in frames with plaster fixation gave unsatisfactory results in earlier years—but it does not follow that hope should be abandoned We shall do better in time when we know more surely

[1] Essex Lopresti, P The Mechanism, Result & Technique in Fractures of the Os Calcis. *Brit. J Surg* 19.., 39, 395

[2] Roberts, N W Symposium on Fractures of the Os Calcis (Annual Meeting of the British Orthopaedic Association, London, 1946). *J Bone Joint Surg* 1947 29 254.

But it is perfectly clear that the most serious disability from fractures of the calcaneum arises from injury to the subtalar joints An extreme example is shown in Figure 1380 The force of vertical compression was so great that the tibia and fibula were driven right through the tarsus The calcaneum lies high above the lower shaft of the tibia behind and the

FIG 1380

Severe vertical compression fracture-dislocation of the foot in which the leg bones were driven right through the tarsal bones. This was in a patient aged sixty five years who also sustained compression fractures of the knee joint on the same side and of the ankle on the opposite side He was treated by my colleague Raymond King at the Oldchurch Hospital, near London The patient is now getting about happily

other tarsal bones lie equally high in front In this patient the severity of the injury to the subtalar joint is very obvious but even when it is less obvious it is no less important

Classification of fractures of the calcaneum—Until recent years there was some confusion in planning treatment and estimating the prognosis of fractures of the calcaneum because there had been no proper classification

which fractures to leave alone, which to replace by operation and which to treat by early arthrodesis

2) *Treatment by skeletal traction and manipulative compression*—This method of treatment devised by Böhler, must be recorded if only to pay tribute to an early pioneer The results were seldom satisfactory but it was a contribution upon which others may build A skeletal traction pin was driven transversely through the heel Traction was applied first in the long axis of the limb and then in a more backward direction against the counter traction of another pin in the tibia (Fig 1399) Lateral spreading of the heel was corrected In earlier years heroic measures of pounding the

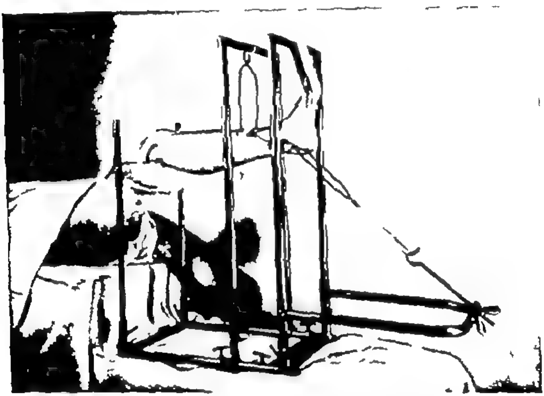

Fig 1399

Reduction of fracture of calcaneum A transfixion pin has been introduced through the lower shaft of the tibia and traction is applied backwards, in the long axis of the tuberosity of the calcaneum. This technique advocated by Böhler is now seldom if ever used.

side of the bone with a hammer or heavy punch had been used [1 2] but this was replaced by the controlled strength of Böhler's clamp with its rubber pads screwed together with known force measured in millimetres on the shaft of the instrument A plaster cast was applied from the toes to below the knee moulded round the malleoli and over the sides of the calcaneum kept in position for about ten weeks The technique has now been abandoned but the principles of it may be used in future developments

3) *Treatment by operative replacement*—When the main line of fracture runs through the body of the calcaneum with displacement only of the

Kindersley, C. F. Fractures of Os Calcis (advocating traction and then disimpaction by means of a punch applied to the plantar surface of the bone). *Proc Roy Soc Med* (Section of Orthopaedics) 1937 30, 123
Hermann, A. J. Fracture of Os Calcis (advocating reduction of widening of the bone by lateral percussion with a hammer). *J Bone Joint Surg* 1937 19, 10.
Pratt, H. G. Concerning the Treatment of Fracture of Os Calcis (advocating disimpaction before applying skeletal traction by lateral percussion with a heavy punch). *Canad med Ass J.*, 1939 41, 40

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It was difficult to understand why one patient with fracture of this bone went back to work happily within a few months, whereas another was seriously disabled for as long as two or three years The fact is that there are as many varieties of fracture of the calcaneum needing different measures of treatment as there are fractures of the knee joint or fractures of the ankle joint Within recent years the classifications of Vidal and Böhler[1] Jaekle and Clark,[2] Warrick and Bremner[3] Essex Lopresti[4] and Palmer[5] have provided a scientific basis for clinical study which give at least a promise of improved results in this difficult group of injuries. The classifications are broadly similar and they all place emphasis on the distinction between fractures of the calcaneum which do not involve the subtalar joint and fractures into the joint with varying degrees of damage and displacement of the joint surfaces

CLASSIFICATION OF FRACTURES OF THE CALCANEUM

In considering fractures of this bone it is essential first to identify fractures which do not involve the subtalar joint and then to distinguish the various types of fracture-dislocation which do involve the joint In the classification here presented tribute must be paid to Warrick of the Department of Radiology in the Royal Victoria Hospital at Newcastle who has allowed me to use many of his radiographs and has helped in the understanding of these fractures A simple classification is proposed and illustrated in Figures 1381 1388 Radiographs of typical injuries are shown in Figures 1389 1397

Fractures of the calcaneum not involving the subtalar joint—

1 Vertical fracture of the tuberosity
2 Horizontal fracture of the tuberosity
3 Fracture of the sustentaculum tali
4 Fracture of the anterior end of the calcaneum

Fractures of the calcaneum involving the subtalar joint—

5 Fracture adjacent to but not entering the subtalar joint
6 Fracture with displacement of the lateral part of the subtalar joint
7 Fracture with central crushing of the whole subtalar joint

1) **Vertical fracture of the tuberosity of the calcaneum**—This fracture is caused by a shearing force sustained from a fall on the heel in the valgus position which often occurs as an isolated injury and causes relatively little disability (Figs 1389-1390) Imperfect reduction may give rise to local thickening with tenderness from projecting spurs There may be tenderness under the heel in the region of the calcaneal tuberosity where the plantar fascia and muscles are attached aggravated by the impact of weight bearing This often needs the protection of hollowing the inside of the shoe with a filling of sorbo rubber The symptom of pain under the heel from the impact

[1] Vidal and Böhler L. Treatment of Fractures Bristol John Wright and Sons Ltd 1935, 4th ed [illegible]
[2] Jaekle H. F., and Clark, A G Fractures of the Os Calcis. *Surg Gyn. Obstet.*, 1937 64, 663.
[3] Warrick, C K and Bremner A E. Fractures of the Calcaneum." *J Bone Joint Surg* 1953, 35-B, 33
[4] Essex Lopresti P. "Mechanism, Technique & Result in Fractures of the Os Calcis. *Brit J Surg* 1952, 39, 395.
[5] Palmer I The Mechanism and Treatment of Fractures of the Calcaneum." *J Bone Joint Surg* 194[illegible] 30-A, 2.

Fig 1400

Fracture of the calcaneum with upward displacement of the tuberosity and loss of the tuber joint angle

Fig 1401

The upward displacement of the tuberosity of the calcaneum has been corrected by means of a skeletal pin driven through the back of the bone

lateral part of the subtalar surface and without complete crushing and destruction of the joint good results may be secured by operative replacement [1 2] The upward displacement of the tuberosity which reduces the tuber joint angle should first be corrected by a skeletal pin driven through the back of the bone (Figs 1400 1401) Then through an incision over the

Palmer I The Mechanism and Treatment of Fractures of the C ... *Bone Joint Surg* 1948 30-A 2
Essex Lopresti, P The Mechanism, Reduction Techniqu ... ractures of the Os Calcis
Brit J Surg 39, 395.
Marckwald O H *Anal de C* 1953, 11 1

of weight bearing does of course occur quite commonly in patients who have never sustained a fracture and the same treatment of protection by excavation of the heel of the shoe is needed—but it is still worse if there has been a fracture of the tuberosity

2) **Horizontal fracture of the tuberosity of the calcaneum**—Fractures involving the upper part of the tuberosity with tilting of a fragment which have been described as beak fractures must be distinguished clearly from avulsion fractures in which an oval shaped piece of bone is pulled away by traction of the tendo Achillis The horizontal fracture of the tuberosity that we are now discussing is not an avulsion fracture The fragment is displaced and tilted upwards but it involves only the upper part of the tuberosity and not the part into which the Achilles tendon is inserted (Figs 1391 1392) It can usually be replaced by simple manipulation and there is seldom need for operative treatment There are of course unusual cases of avulsion of the tuberosity or its epiphysis by the tendo Achillis in which operative replacement and suture may be needed The distinction should be quite clear The horizontal or beak fracture involves only the upper third of the tuberosity and it lies well above the insertion of the tendon

3) **Fracture of the sustentaculum tali**—This fracture is produced by violence applied to the inner side of the foot while it is in an everted or valgus position (Fig 1393) As an isolated injury it constitutes less than one per cent of all fractures of the calcaneum The displacement is usually slight and the injury gives rise to little disability

4) **Fracture of the anterior end of the calcaneum**—Isolated fractures of the anterior end of the calcaneum may be sustained from forcible twisting of the foot (Fig. 1394) The line of fracture extends obliquely into the calcaneo-cuboid joint so that a small triangular fragment is detached from the front of the bone There is seldom displacement and the fracture unites quickly Occasionally there may be displacement of a larger fragment with such irregularity of the articular surface of the calcaneo-cuboid joint as to threaten traumatic osteoarthritis in later years

5) **Fractures of the calcaneum without displacement**—When there has been vertical compression with injury to the body of the calcaneum the basic line of fracture runs from the postero-medial to the antero lateral aspect of the bone separating a small postero-medial fragment with the medial part of the subtalar joint and sustentaculum tali from a larger postero-lateral fragment with most of the tuberosity of the bone and the lateral part of the subtalar joint This fracture sometimes occurs without displacement of the subtalar surfaces because at its anterior limit it just escapes the joint and lies lateral to it (Fig 1395) No problem of traumatic arthritis then arises although of course there is still thickening and broadening of the bone and there may also be upward displacement of the tuberosity with loss of the tuber joint angle and the functional disabilities associated with it If these displacements are corrected by manipulation and the foot is immobilised in plaster complete functional recovery is to be expected

6) **Fractures with displacement of the lateral part of the bone and lateral half of the subtalar joint**—The main line of fracture extending from the postero-medial to the antero-lateral aspect of the bone is usually associated with displacement of the lateral fragment carrying with it a large part of the subtalar joint surface (Fig 1396) It is obvious that if such displacement

side of the heel just behind the peroneal tendons the downwardly displaced lateral part of the bone with the lateral part of the subtalar joint surface is elevated. This leaves a gap where the cancellous bone in the middle of the calcaneum has been crushed. This is filled with cancellous grafts taken from the ilium.

It must of course be understood that these measures of operative replacement of fractures of the calcaneum with involvement of the subtalar joint have been under trial only for a limited period. We do not yet know whether the results will prove to be better than those from early arthrodesis of the joints.

(4) *Treatment by primary arthrodesis*.—When crushing of the whole subtalar joint is of such a degree that the best functional result to be expected is ankylosis it is best to promote this by early operation. The operation should usually be deferred until two or three weeks after injury.

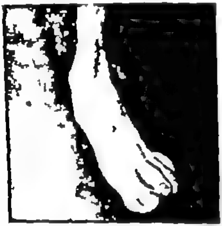

FIG. 1402

Valgus deformity of the foot after fracture of the calcaneum aggravated by peroneal spasm from subtalar arthritis—spasmodic flat foot.

FIG. 1403

Subtalar arthrodesis for fracture of calcaneum with complete destruction of the joint surfaces. This time the calcaneo-cuboid joint was not fused.

It is wise to correct serious deformity within the first few days by simple manipulation under anaesthesia—particularly correcting the lateral spread and the valgus deformity of the heel by simple compression between the surgeon's two hands, the foot then being supported in a light plaster cast. After two or three weeks the joint is exposed, fragments of cartilage are removed, the surfaces are thoroughly freshened, and if need be cancellous bone grafts cut from the ilium are impacted. My own preference is to use a lateral approach like that used for stabilising operations on the paralytic foot, especially since there may be need to fuse the calcaneo-cuboid joint. Others prefer the posterior approach described by Gallie[1] and Lawson Dick.[2] A padded plaster is applied which should be replaced after two or three weeks by an unpadded cast closely moulded on each side of the heel in such a way as to prevent recurrence of lateral thickening and to keep

[1] Gallie, W. E.: "Subastragalar Arthrodesis in Fractures of the Os Calcis." *J. Bone J. Surg.*, 1943, 25, 731.
[2] Dick, I. L.: "Primary Fusion of the Posterior Subtalar Joint in the Treatment of Fractures of the Calcaneum." *J. Bone Joint Surg.*, 1953, 35-B, 375. The particular significance of Lawson Dick's contribution was the principle he advocated of fusing the joint without need for the external support of plaster—but I am not yet convinced that this is wise. It does no harm at all to put a fractured foot in plaster for a few months and it does no harm to protect arthrodesis of the tarsal joint in plaster.

is not corrected there will be serious disturbance of the subtalar joint with at least fibrous ankylosis and perhaps persistent and painful osteoarthritis In addition to this primary fracture there is usually at least one secondary line of fracture, roughly parallel with the first involving the lateral cortex of the bone Between them the main mass of the tuberosity with the lateral part of the subtalar joint is crushed down with the tilting described so graphically by Morestin [1] as like a see-saw down in the front and up at the back The cancellous bone beneath it in the middle of the calcaneum

FRACTURES OF THE CALCANEUM NOT INVOLVING THE SUBTALAR JOINT

FIG 1381
Vertical fracture of the tuberosity

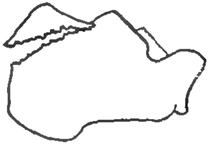

FIG 1382
Horizontal fracture of the tuberosity

FIG 1383
Fracture of the sustentaculum tali

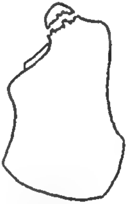

FIG 1384
Fracture of the anterior end of the calcaneum

is crushed Nevertheless there is not complete destruction of the whole subtalar joint surface and operative replacement may still succeed in restoring good function

7) **Fractures with central crushing and displacement of the whole of the subtalar joint**—There is sometimes even greater comminution and crushing of the subtalar joint—the fracture with so-called centro lateral compression—perhaps also with comminution of the calcaneo-cuboid joint and with avascular necrosis of many separated fragments thus leading almost certainly to traumatic arthritis and needing arthrodesis of the joints (Fig 1397).

[1] Morestin, 1902, quoted by Schwartz, M. A *Bull. Soc. nat. Chir* 1929, 55, 113.

the heel in a strictly neutral plane with no valgus deformity—but it must be added and with still greater emphasis with no varus or inversion deformity which is so much more disabling after subtalar arthrodesis

5) *Treatment of fractures of the calcaneum by complete excision of the bone*—It may be mentioned in passing that Pridie suggested complete excision of severely comminuted fractures of the calcaneum One or two other surgeons have done the same mutilating operation [1 2] It is of course astonishing that such excellent function can be regained after complete excision of this bone through a posterior split-heel incision and the procedure may have its surgical applications—but surely not to the routine treatment of fractures of the calcaneum

Summary of the treatment of fractures of the calcaneum—It is obvious that there is still considerable divergence of opinion as to the best method of treating serious fractures of the calcaneum in which there is crushing of bone with involvement of the subtalar joint The measure of success to be expected from the different types of treatment may be more clear when the results of the many clinical investigations now being pursued are known Meanwhile the principles of treatment to be accepted are —

1 Fractures not involving the subtalar joint need only the support of a light plaster cast or a crêpe bandage for a few weeks
2 Fractures in the basic line from the postero medial to the antero-lateral aspect but escaping the subtalar joint should be treated by manipulative reduction of the upward displacement of the tuberosity and the broadening of the heel, with immobilisation in plaster for eight or ten weeks
3 Fractures in the same basic line of fracture but entering the subtalar joint should be treated in young patients by operative replacement of the displaced fragment using cancellous iliac grafts to fill the space of the compressed bone
4 Similar fractures in middle aged or elderly patients should be treated by simple bed rest for a week or two with no more than simple endeavours to reduce the lateral thickening and valgus deformity by manipulation but without prolonged fixation in plaster
5 Severely comminuted fractures with complete destruction of the joint surfaces should be treated in patients of all ages by early arthrodesis

DISLOCATIONS AND FRACTURE-DISLOCATIONS OF THE TALUS

To understand the treatment of fractures of the neck of the talus and other fractures and fracture-dislocations of this bone we must first study the mechanism of injury because otherwise it is difficult to recognise the best methods of manipulative replacement In earlier surgical contributions these injuries were described as simple and double luxations or primary secondary and tertiary luxations depending upon whether there was involvement of one two or three of the tarsal joints [3 4] This was really no

Pridie K "Symposium on Fractures of the Os Calcis at the Annual Meeting of the British Orthopaedic Association. *J Bone Joint Surg* 1947, 29, 535.
Cleminson, K Excision of Calcaneum for Fracture " *J Bone Joint Surg*, 1952, 34-B, 114
Baudet, R Contribution a l'Etude des Fractures d Astragale (full review and bibliography). *Th. Chir Paris*, 1914, 64, 305.
Schmitt, W Zu operativen Behandlung der Talus-luxation (detailed list of earlier references). *Deut. Z Chir* 1914 130, 321
Bonnin, J G Dislocations and Fracture-dislocations of the Talus." *Brit Surg* 1940 28.

FRACTURES OF THE CALCANEUM INVOLVING THE SUBTALAR JOINT

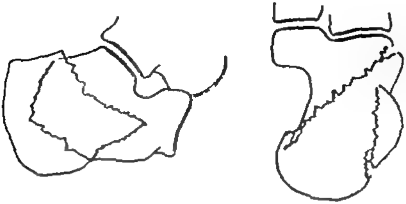

FIG 1385

Fracture with displacement adjacent to but not entering the subtalar joint.

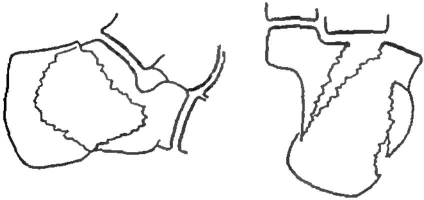

FIG 1386

Fracture with displacement of the lateral half of the subtalar joint.

FIG 1387

FIG 1388

Fracture with central crushing of the whole subtalar joint (Fig 1387) and of the calcaneo-cuboid joint (Fig 1388)

more than an academic exercise it was confusing and of little value in treatment Injuries of other joints are usually classified in accordance with the mechanism of injury and the direction of displacement For example injuries of the ankle joint are grouped into fractures with lateral or postero-lateral displacement fractures with medial or postero-medial displacement fractures with posterior displacement and fractures with anterior displacement Similarly fractures of the neck of the humerus have been classified as contusion injuries fractures with adduction displacement and fractures with abduction displacement So it is with the injuries of all other joints Fracture-dislocations of the talus should also be grouped in accordance with the direction of violence into 1) inversion injuries 2) dorsiflexion injuries 3) adduction and abduction injuries

Inversion injuries causing displacement of the talus (Figs 1404-1406)—Forcible inversion of the foot may rupture the lateral ligament of the ankle and cause momentary dislocation—thus we have discussed With similar stress but with the foot more plantar flexed at the time of injury the interosseous ligaments of the subtalar joints may be torn—the tarsal bones being dislocated inwards while the talus remains undisplaced in the tibio-fibular mortise—*subtalar or talo-calcaneal navicular dislocation* If all the ligaments not only those of the subtalar joint but also those of the lateral side of the ankle joint are torn simultaneously the talus is separated not only from the other tarsal bones but also from the tibio-fibular mortise so that there is *total dislocation of the talus* This is a combined medial dislocation of the ankle joint with medial dislocation of the subtalar joint The lateral ligament of the ankle joint and the interosseous ligament of the subtalar joint are both ruptured. At the moment of greatest inversion the talus is rotated 90 degrees about its vertical axis so that the head is directed medially it is also rotated 90 degrees about its long axis so that its inferior surface is directed backwards When violence ceases and the foot springs back to the neutral position the dislocated talus remains in this rotated position and lies with the body in front of the lateral malleolus the head on the medial side the calcanean surface directed backwards and the tibial articular surface under the skin

Dorsiflexion injuries (Figs 1407 1410)—An entirely different injury causes fracture of the neck of the talus with dislocation of the body The type of displacement is different the method of reduction is different and the after treatment is different This injury is not to be classified with total dislocations of the talus It arises from forced dorsiflexion of the foot Violent dorsiflexion is an infrequent strain in civilian life and fracture-dislocations of the neck of the talus are unusual injuries Nearly all reports in the literature are based on one or two cases But it is a frequent complication of flying accidents

Graeme Anderson reported eighteen such fractures sustained by members of all the flying services in the 1914 18 war[1] In the more recent war of 1939 1945 we were able to treat and with the aid of my colleague Coltart[2] to study no less than 228 such injuries It is true that these were from approximately 23 000 severe fractures and dislocations treated by surgeons in the orthopaedic units of the Royal Air Force Even so that represents

[1] Anderson, H. Graeme "Medical and Surgical Aspect of Aviation." London Oxford Medical Publications, 1919
[2] Coltart, W D. "Aviator's Astragalus." J Bone Joint Surg 1952, 34-B, 545.

FIG. 1389
Vertical fracture of the tuberosity of the calcaneum.

FIG. 1390
Vertical fracture of the tuberosity with mal-union.

FIG. 1391
Horizontal fracture of the tuberosity of the calcaneum. It was easily reduced by manipulation.

FIG. 1392
Horizontal or "beak" fracture of the tuberosity with still greater tilting and displacement of the fragment.

FIG. 1393
Isolated fracture of the sustentaculum tali.

FIG. 1394
Isolated fracture of the anterior end of the calcaneum.

With two exceptions all the radiographs shown in Figures 1389-1397 are by courtesy of C. K. Warrick and have been published in the Journal of Bone and Joint Surgery, 1953, 35-B, 33. I am grateful to Mr Warrick and to the Editor and Publishers of the Journal.

an incidence of only 1 per cent of all major fractures and dislocations or 6 per cent of injuries of the foot and ankle

It is reasonable to describe this injury as the aviator's fracture The injury is the result of a head-on crash and it is sustained by a pilot whose feet are on the rudder bar The rudder bar lies under the instep or forefoot

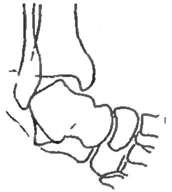

FIG 1404
Dislocation of the ankle joint.

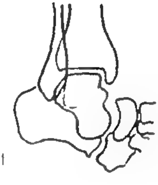

FIG 1405
Dislocation of the subtalar joint

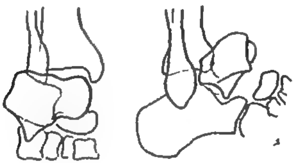

FIG 1406
Total dislocation of the talus.

Inversion injuries of the talus

Inversion strain ruptures the lateral ligament of the ankle joint (Fig. 1404), the interosseous ligament of the subtalar joint (Fig 1405), or both the lateral ligament and the interosseous ligaments (Fig. 1406) Note that when the foot is inverted and plantar flexed the talus is rotated (Fig 1404)—and that after total dislocation of the talus it remains locked in this position (Fig 1406)

and as it is driven backwards the foot is forced into dorsiflexion The neck of the talus is impacted against the anterior margin of the lower end of the tibia which drives into the talus like a chisel and causes a *vertical fracture of the neck of the talus* As a rule there is also damage to the anterior tibial margin If violence continues the line of injury extends from the neck of the talus to the ligaments of the posterior part of the subtalar joint and the whole foot subluxates forwards on the body of the talus—*fracture of the neck of the talus with subtalar dislocation* [1] As the foot continues to dorsiflex

[1] It must be understood that only the posterior half of the subtalar joint is dislocated. There is no displacement between the head of the talus and the anterior facet of the calcaneum. Described in full, the injury is a fracture of the neck of the talus with dislocation of the posterior half of the subtalar joint and the final degree of displacement is a fracture of the neck of the talus with dislocation of the posterior half of the subtalar joint with backward displacement of the body of the talus For brevity it is described throughout the text as fracture of the neck of the talus with subtalar dislocation. The last degree of injury is described as fracture of the neck of the talus, subtalar dislocation with backward displacement of the body

and displacement increases, the tuber calcanei comes to lie under the body of the talus But it is obvious from examination of the disarticulated bones that it will be the medial surface of the tuber that lies under the talus (Figs 1422 1425) The curved posterior facet of the calcaneum leads directly backwards to this surface While it is in this position the sustentaculum

Fig 1407
Fracture of the neck of the talus without displacement.

Fig. 1408
Fracture of the neck of the talus with subtalar dislocation.

Fig 1409

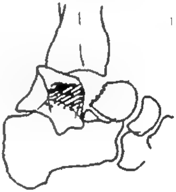

Fig 1410

Fracture of the neck of the talus with subtalar dislocation and backward displacement of the body

Dorsiflexion injuries of the talus

Forcible dorsiflexion fractures the neck of the talus by impact against the anterior margin of the tibia (Fig 1407) *If violence continues the posterior half of the subtalar joint is dislocated* (Fig. 1408). With still more displacement the tuber calcanei locks under the body of the talus (Fig. 1409) and when violence ceases, and the foot is plantar flexed once more the body of the talus is displaced backwards (Fig 1410)

tali of the calcaneum locks in front of the medial tubercle of the body of the talus Thus when violence ceases and the foot is once more plantar flexed the locked body of the talus is displaced backwards out of the tibio fibular mortise It lies on the medial surface of the tuber calcanei with its fractured surface directed laterally its trigonal tubercle medially and its medial tubercle hooked behind the sustentaculum tali—*fracture of the neck of the talus with subtalar dislocation and posterior displacement of the body*

FIG 1434
Six months after reduction.

FIG 1435
Twelve months after reduction.

revascularisation, proved by areas of decalcification beginning in the region of the fracture and gradually spreading backward (Fig 1434). The last area to revascularise was the subchondral region and articular surface of the ankle joint. Both ankle and subtalar joint suffered some degree of degenerative arthritis shown in the narrowed joint spaces (Fig 1435), but there was a satisfactory range of painless movement and good function.

FIG. 1415

Fracture of the neck of the talus. Is there displacement of the fragments? After making a decision, raise the flap below and see Figures 1416 and 1417

Do not raise this flap until Fig 1415 has been examined and a decision made

Raise flap to see Figs 1416 and 1417

density of the talus because in the lateral radiograph one part of the bo is overlapped by the shadows of both medial and lateral malleoli th density of this area is always three times that of normal bone. The diagno of avascular necrosis must be made on the evidence of relative density in th regions where there is no overlap of bone shadows. Weight bearing shou be deferred for two or three months. Immobilisation in a walking plast is then continued for several months longer. Continued protection preven crushing of the bone and minimises the danger of degenerative arthritis the ankle and subtalar joints. In some cases excellent function may b regained with a satisfactory range of painless movement.

Fig. 1436

Fracture neck of talus with subtalar dislocation and posterior displacement of the body after manipulative reduction, showing an associated fracture of the medial malleolus with interposition of a periosteal flap accounting for failure of accurate replacement

Arthrodesis for degenerative arthritis—Degenerative arthritis may supervene in the ankle and subtalar joints after several months or years. If only one joint is involved it should be arthrodesed. Even when both joint are involved there should be no hesitation in performing a tibio-calcanean fusion. In a study of seventy five fractures and dislocations of the talus the most striking inference was that the results of excising the talus were uniformly bad and the results of tibio-calcanean fusion were surprisingly good (Figs 1437 1441). Through an antero-lateral incision the lower shaft of the tibia the ankle joint and the subtalar joint are exposed. Degenerated cartilage is removed from both joints inversion deformity is corrected and the foot is held in the optimal position 10 degrees below the right angle. A trough is cut in the tibia and talus with a socket in the calcaneum. A graft is removed from the opposite tibia, or from the same tibia at a higher level. It is driven into the socket of the calcaneum and inlaid in the trough

FIG 1418

Fracture of the neck of talus with the subtalar dislocation.

FIG 1419

After manipulative reduction by full plantar flexion and eversion of the foot

FIG 1420

Same case as shown in Figures 1418-1419 six months after reduction and immobilisation. Movements of the ankle mid tarsal and subtalar joints are normal, and the patient has no disability If the fracture-dislocation is completely reduced, there is no danger in immobilising the foot for eight weeks in full plantar flexion and eversion

FIG. 1437

Old unreduced fracture of neck of talus with subtalar dislocation, complicated by avascular necrosis of the body of the talus, which is relatively dense

FIG. 1438

Same case as shown in Figure 1437. It was treated by excision of the body and head of the talus. Function was good for two years, but it rapidly deteriorated after that until in five years time the patient could scarcely walk. Tibio-calcanean fusion was then performed. See also Figures 1441 1442.

CHAPTER XXXIV

FRACTURES AND DISLOCATIONS OF THE SPINE WITH PARAPLEGIA

"*An ailment not to be treated* —EDWIN SMITH papyrus 3000 B.C.

Patients with paraplegia should be treated either superlatively well or not at all."
—E. A NICOLL, A.D 1953[1]

Three thousand years before Christ an unknown surgeon inscribed an Egyptian papyrus with his belief that spinal injury with paralysis was an ailment not to be treated It is not surprising that it was then thought unwise to perpetuate a state of misery which could not be relieved but it is perhaps surprising that fifty centuries should have elapsed before any alleviation of this tragic fate could be offered to the victims of traumatic paraplegia who so often are struck down in the prime of their lives Even until very recent years only five or ten years nearly every patient who sustained fracture-dislocation of the spine with permanent paralysis died very soon They lay rotting in bed with large stinking pressure sores which increased in size as emaciation got worse until the bones of the pelvis and sacrum were exposed lacking sensation incapable of movement often with distressing involuntary spasm and secondary contracture of joints, incontinent of urine and fæces with infection of the urethra bladder and renal tract They were doomed to die within a few years from inanition uræmia and pneumonia (Fig 1561)

Of the American soldiers who sustained traumatic paraplegia in the first world war one alone was alive twenty years later So it was in Britain and elsewhere throughout the world They all died and they all died miserably Despite the early endeavours of Gordon Holmes[2] in England Major Gowlland wrote from the Star and Garter Home for paraplegics enough sedatives must be given to counteract the shock which is intensified by contemplating years of inaction and invalidism more morphine atropine and hyoscine is used in this home than in any other place of the same size ' There was only a spark of optimism when he went on to write after complacency has been established life in these cases is not necessarily miserable [3-4] These were the key words relating to traumatic paraplegia—inaction and invalidism, morphine and hyoscine complacency and misery decubitus ulceration and emaciation urinary infection and uræmia, exhaustion and death

A new hope has been born It is now much more than a hope—it is a proved experience Munro of Boston[5] who was the great pioneer recent

Nicoll, E. A. Injuries to the Back. *Brit. med. J* 19.3, 1 929
Holmes G. *Brit. med. J.*, 1915, 2, 769 815, 855
Gowlland, E. L. *Med. Press*, 1934 188, 61
Gowlland, E. L. *Brit. med. J.*, 1941 1 814.
Munro, D. Rehabilitation of Veterans Paralysed as Result of Injury to the Spine
Amer J Surg 1948, 75, 3-18.

of the talus and tibia If necessary a screw may be used for fixation Desp rigidity of the foot the sound ankylosis and complete freedom from pa allow the patient to walk with little limp and to run jump play games a resume all normal activities

Arthrodesis after loss of the talus—The final results of excision of the tal have been almost uniformly bad Inversion deformity develops rapid

FIG 1430

Tibio-calcaneum fusion after excision of the talus

The photograph on the left shows the region exposed before freshening the bone surface and grafting A graft was fixed in a socket in the calcaneum and inlaid in a trough in the tibia; it has been impacted with the cortical surface down, and the medullary surface is shown in the trough a second graft was then fixed between tibia and navicular Finally the interspaces were filled with bone chips.

The gait is halting and painful A surgical boot with an inside iron and outside T strap is usually needed One patient whose talus I removed went back to heavy work as a miner and for five years both the patient and the surgeon were satisfied Two years later the patient was less satisfied after three years he stopped work and after four years he could scarcely walk I then arthrodesed the joints When the whole of the talus is missing including the head it is usually necessary to arthrodese the tibia calcaneum and navicular After freshening the opposing bone surfaces and driving

and suture the fragment in position. In one case after manipulative reduction, it was found that the medial malleolus was interposed between the head and body of the talus. It was obstructing accurate reduction of the fracture of the neck. The fragment was withdrawn and sutured in its normal position.

FIG. 1422

FIG. 1423

Superior aspect of calcaneum. The curved plane of the posterior facet leads directly to the medial surface of the tuber calcanei and guides the body of the talus to this position after fracture of the neck of the talus with subtalar dislocation.

FIG. 1424

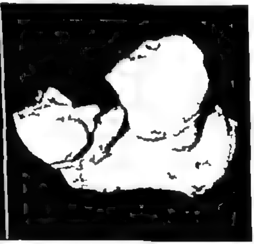

FIG. 1425

Position of the body of the talus in the third degree of displacement. The medial tubercle is locked behind the sustentaculum tali. With the disarticulated bones in his hands it is easy for the surgeon to teach himself the mechanism of displacement and the principle of reduction. Try it.

Avascular necrosis of the body of the talus—When the body of the talus is completely dislocated backwards all soft-tissue attachments may be torn. If the bone is entirely deprived of its blood supply avascular necrosis is inevitable. The diagnosis is established by the radiographic evidence of relative density. Care must be taken in accepting evidence of relative

FIG 1440

FIG 1441

Tibio-calcaneal arthrodesis for avascular necrosis of the talus and degenerative arthritis of the ankle and subtalar joints (Fig 1440) A graft cut from the upper shaft of the tibia has been inlaid in tibia and talus and impacted into a socket in the calcaneum A single screw was used to fix the graft at the upper end where it tended to spring The radiograph four months after operation (Fig 1441) shows sound fixation of both joints

FIG 1426

FIG 1427

FIG. 1428

Figs. 1426-1430—Fracture of the neck of the subtalar posterior
displacement of the body during and after m by wire.

Displacement is typical (Fig 14*6) The l on the tuber
calcanei, and it is rotated so that the frac lative

a graft between the tibia and calcaneum a second graft is inserted from the tibia to the navicular and the intervening spaces are filled with bone chips

FRACTURES OF THE TARSAL NAVICULAR BONE

Three types of fracture of the navicular are to be distinguished 1) fracture of the tuberosity 2) fracture of the dorsal lip 3) transverse fracture with dislocation of the dorsal fragment

Fracture of the tuberosity of the navicular—The tuberosity of the navicular may be avulsed by the tibialis posterior This tendon has so many extensions to neighbouring bones that the separated fragment is seldom displaced widely and operative replacement is usually unnecessary The foot should be immobilised in plaster for about ten weeks and the functional result is nearly always good

Congenital os tibiale externum—Fracture of the tuberosity of the navicular is to be distinguished from the congenital anomaly of ossification in which the tuberosity develops from a second centre of ossification—known as the os tibiale externum The line of separation is then quite smooth and regular and the congenital anomaly is usually bilateral In both congenital and traumatic separations of the tuberosity excision of the detached fragment may be needed if there is persistent pain

Fracture of the dorsal lip of the navicular—A small flake of bone may be avulsed from the dorsal surface of the navicular Immobilisation in plaster is required only for a short period The results are excellent

Transverse fracture of the navicular—The body of the navicular is fractured transversely in a horizontal plane so that the bone is divided into a large dorsal and small plantar fragment The large fragment is dislocated upwards from the talo navicular cuneiform joints It is usually possible to replace the displaced fragment by pressure over its dorsal surface while the foot is held in plantar flexion but redisplacement is liable to occur despite a closely moulded plaster Redisplacement can be prevented by the counter traction of a pin through the calcaneum and a Kirschner wire through the bases of the metatarsals the pin and wire being left in position and incorporated in the plaster Occasionally the navicular is impacted on the dorsal lip of the head of the talus and cannot be reduced except by open operation (Figs 1442 1444) But whether the dislocated fragment is reduced by manipulation skeletal transfixion or open operation the sequel is usually the same The fragmented bone often undergoes absorption and the small plantar fragment may disappear altogether Arthritis develops in the talo-navicular and naviculo-cuneiform joints and good function is secured only when the joints become firmly ankylosed by dense fibrous tissue The disability period is prolonged There can be little doubt that the treatment of choice is immediate arthrodesis of both joints An incision is made over the bone articular cartilage is denuded the dislocated fragment is replaced and a small graft cut from the tibia or ilium is inlaid in a trough cut from the head of the talus to the medial cuneiform The foot is immobilised in plaster until union is sound usually ten weeks after operation

Fig. 1429

Fig. 1430

reduction failed. It was reduced under radiographic control after transfixion of the bone by a Steinmann pin (Figs. 1427-1429). The radiograph six weeks later confirms that reduction is still accurate but shows evidence of relative density and avascular necrosis of the body (Fig. 1430).

Fig. 1442

Fig 1443

Fig 1444

Transverse fracture of the navicular with dislocation of the large dorsal fragment Attempted reduction by plantar flexion and direct pressure over the fragment failed (Fig 1442) An attempt was then made by skeletal traction from a Steinmann pin in the calcaneum and Kirschner wire in the metatarsals (Fig 1443); this also failed The navicular was impaled on the dorsal lip of the head of the talus and it was reduced only by operative exposure (Fig 1444) Despite accurate reduction,

FIG. 1431
Fracture of neck of talus with backward displacement of body

FRACTURE-DISLOCATIONS OF THE MID-TARSAL JOINT

The mid tarsal or talo navicular calcaneo-cuboid joint may be dislocated by abduction or adduction stresses applied to the foot Manipulative reduction is seldom difficult and if there is no associated fracture of the tarsal bones good function is restored quite quickly Sometimes however the dislocation may be associated with fractures of the navicular or cuboid bones A crushing injury such as is produced when the wheel of a lorry is driven over the foot or when a heavy weight falls upon it may comminute the tarsal bones and drive the navicular into the head of the talus or the cuboid into the front of the calcaneum In these circumstances even when the mid tarsal dislocation is replaced there is often persistent disability from traumatic arthritis of the injured joints with widespread osteoporosis adhesion formation painful stiffness and other disuse changes It is better to anticipate these disabilities after reduction of the dislocation by arthrodesing the mid tarsal joint within two or three weeks sometimes using free grafts of cancellous bone cut from the ilium to accelerate the surgical fusion Of course the foot should be immobilised in plaster after operation for about three months

Mid tarsal dislocation with paralysis of the plantar nerves—A dislocation of the mid tarsal joint shown in Figure 1445 was associated with injury to the medial and lateral plantar nerves, causing anaesthesia of the plantar surfaces of the toes and paralysis of the lumbar and interosseus muscles with claw-deformity of the toes just like main-en-griffe from corresponding paralysis of the hand The phrase *pied-en-griffe* may not have been used before but it gives an exact description of the disability In tarsal and metatarsal injuries special attention should be paid to the possibility of associated injuries to the plantar nerves and the blood vessels of the foot as well as to the neuro-vascular bundle behind the medial malleolus

FRACTURE-DISLOCATIONS OF THE TARSO-METATARSAL JOINT

Tarso-metatarsal dislocations were hallowed in history at Waterloo In the campaigns of Napoleon and Wellington, Lisfranc developed his amputation at the tarso-metatarsal level for closed injuries of the foot He knew the perils of gangrene from this injury long before we knew the pathogenesis of traumatic arterial spasm and ischaemia [1 2] Of course most tarso-metatarsal dislocations may be treated safely by simple manipulative reduction—the more promptly the better—with immobilisation in a padded plaster cast and elevation of the limb during the first few days But as Cissane has pointed out this is a dangerous type of fracture [3] Lateral rotation or pronation force, in dislocating the forefoot may separate the bases of the first and second metatarsals and rupture the dorsalis pedis artery It may also twist the main vessels behind the medial malleolus and cause arterial spasm and thrombosis of the main plantar vessels The essential points of treatment are 1) to reduce the displacement promptly and completely whether by

Lisfranc J "Nouv lle Methode Operat ire pour l'Amputation Partielle du Pied." Paris: Gabon 1815.
Lisfranc J Fractures Compliquees Reflections sur l'epoque la plus opportune pour application de l'appareil Gaz d'hop Pa is, 1840 2, 27
Cissane W A Dangerous Type of Fracture of the F ot. J Bone Joint Surg 1951 33-B, 533.

Fig. 1434

Six months after reduction.

Fig. 1433

Twelve months after reduction

revascularisation, proved by areas of decalcification beginning in the region of the fracture and gradually spreading backwards (Fig. 1434). The last area to revascularise was the subchondral region and articular surface of the ankle joint. Both ankle and subtalar joints suffered some degree of degenerative arthritis shown in the narrowed joint spaces (Fig. 143[illegible]), but there was a satisfactory range of painless movement and good function.

FIG 1445

FIG 1446

FRACTURE-DISLOCATION OF MID-TARSAL JOINT WITH INJURY TO THE PLANTAR NERVES CAUSING "PIED-EN-GRIFFE"

This mid tarsal dislocation was unusual in the association of a comminuted fracture of the calcaneus. There was also injury to the medial and lateral plantar nerves causing anæsthesia of the plantar surface of the toes with paralysis of the lumbrical and interosseous muscles giving rise to clawing of the toes similar to that of main-en griffe deformity of the hand from paralysis of the ulnar nerve In all tarsal, tarso-metatarsal and metatarsal injuries of the foot the possibility of injury to the plantar nerves and to the dorsalis pedis and posterior tibial vessels must be considered

FIG. 1431
Fracture of neck of talus with backward displacement of body

FIG. 1432
Immediately after reduction

FIG. 1433
Six weeks after reduction.

Figs. 1431 1433.—Fracture-dislocation of the talus with avascular necrosis of the body and revascularisation

The radiograph six weeks after reduction shows relative density of the body of the talus, thus proving loss of blood supply. Immobilisation in plaster and protection from weight bearing were continued for many months. Serial radiographs showed gradual

gentle manipulation or by open operation and internal fixation (2) to maintain the reduction by means of a suitably padded plaster cast with high elevation of the limb (3) to defer weight-bearing for at least two months. The management of threatened ischæmia and gangrene was discussed in the first volume on pages 108 to 121

FRACTURES OF THE METATARSALS

Avulsion fracture of the base of the fifth metatarsal bone[1 2]—The peroneus brevis is inserted into the tubercle at the base of the fifth metatarsal bone Severe inversion stresses applied to the foot may give rise to a crack fracture or to complete avulsion of the fragment of bone (Fig 1447) This fracture must be distinguished from the normal epiphysial line at the base of the tubercle which is present in children Usually there is no displacement and the only treatment needed is simple strapping of the foot Sometimes a walking plaster may be needed for about six weeks

FIG 1447
Avulsion of base of fifth metatarsal by peroneus brevis tendon (Jones Fracture)

FIG 1448
Fracture of necks of second to fifth metatarsals.

Fracture of the necks of the metatarsals—Simple crack fractures of the necks of one or more metatarsal bones occurring from simple weight bearing stresses such as marching have already been considered in Volume I under the heading of March Fracture More complete fractures of the metatarsal necks arising from severe injury are still more serious because there is usually displacement of the metatarsal heads into the sole which if not reduced gives rise to serious disability (Fig 1448) If the bones are allowed to unite in this position the undue prominence of the metatarsal heads in the tread causes pain every time an attempt is made to step forwards so that the patient may be completely crippled It is usually possible to correct the displacement by simple manipulation with the application of a plaster extending well beyond the metatarso-phalangeal joints to include the toes

Jones, Robert Orthopedic Surgery of Injuries London Oxford Medical Publications, 1921 1 44.
Holland C Thurstan, J Anat., 1921 55, 23.

in their corrected position Seldom is there need for the traction that was formerly advised by means of loops of stainless-steel wire passed through the pulp of the toes and fixed to a spreader Very occasionally when manipulative reduction fails it may be wise to correct the deformity by means of an open operation [1]

Fractures of the metatarsals with gangrene of the forefoot—The ischæmic changes already noted in tarsal and tarso-metatarsal injuries of the foot may also complicate fractures of the necks of the metatarsal bones One such case is shown in Figures 1449 1450 It is true that in this case there had been long exposure on the side of a mountain which in itself impaired the vascular supply The reader may refer back to page 203

Mal united fractures of the necks of the metatarsal bones—When a fracture of the metatarsal bone has united with the head displaced into the sole and the patient complains of severe and persistent pain whenever weight is borne under the tread with a sensation like that of walking on a stone the disability should be relieved by excision of the metatarsal head through a dorsal incision

FRACTURES OF THE TOES

Fractures of the proximal phalanges of the toes show the same displacement as the corresponding fracture of the phalanges of the fingers The tension of the lumbrical and interosseous muscles causes angulation and if this is not corrected the toe remains clawed and a bony lump develops on the plantar surface with persistent tenderness and pain The symptoms may necessitate amputation and if several toes are fractured the resulting disability is serious The displacement should be reduced by flexing the toes and immobilising them in a full length below knee plaster

Comminuted fracture of phalanges of the great toe—The most frequent injury to the forefoot is a comminuted fracture of one or both phalanges of the great toe from the dropping of a heavy weight The fragments are seldom displaced and the protection of a collodion gauze dressing is adequate Immediate weight-bearing is allowed in a boot with the toe-cap cut out and a metatarsal bar screwed on the sole at the level of the tread

Fracture of the sesamoid bones of the great toe—The dropping of a weight on the foot may crush the sesamoid bones of the great toe between the metatarsal head and the ground The fracture is comminuted One or both sesamoids may be involved The injury must be distinguished from congenital bipartite and tripartite sesamoids Fracture of the bone involves the articular surface and since the whole of the body weight is transmitted through this joint with every step the resulting disability may be serious It is sometimes necessary to excise the sesamoid After operation a metatarsal bar may be fitted behind the tread of the sole in order to relieve weight-bearing The disability is often prolonged and it is often necessary to continue suitable protection by metatarsal bars or sorbo-insoles for several months

[1] Mich, K. "Operative reduction of Metatarsal Fractures." *Med. Rec* *N Y.*, 1942, 155, 85

relationship so that when they are wired together an oblique pull will be secured When all ligatures are in position the fracture is reduced by manipulation Each opposing pair of eyelets is then secured by passing wire through the loops and twisting it tightly (Fig 1452) The splinting of patients so treated should be inspected daily for the first fortnight and every other day thereafter until the wires are removed This is necessary because the wires loosen and occasionally break with consequent inadequate immobilisation The wires should be protected from breaking by the additional support of a firm jaw bandage

FIG 1452
Fracture of the mandible immobilised by interdental wiring

Arch-wire method—The technique of interdental wiring has been facilitated and improved by the introduction of arch wires These are curved metal rods which can be fixed accurately to the teeth of the upper and lower jaws by means of dental wiring They are placed on the buccal side of the teeth near the necks and are fitted with studs by which the two arch wires can be secured to each other with simple wires or elastic bands

Cap splinting—Interdental wiring and arch wiring are useful emergency measures and when there is a good complement of teeth and little tendency to displacement they may suffice for the whole treatment But these methods fail when there is marked tendency to displacement The fixation is not sufficiently stable Constant readjustment and tightening is necessary and the wires are liable to break More reliable fixation can be secured with the aid of a skilled dental surgeon by cap splints made of cast metal or acrylic resin

FIG 1453
Fracture of the mandible immobilised by cap splints with lock pin

The splints are specially constructed to plaster casts of the teeth and they are cemented to the teeth thus giving positive and stable immobilisation With the incorporation of locking devices flanges and hooks many of the problems which are difficult of solution with wiring methods are easily overcome Splints applied to the upper and lower jaw may be fixed to each other by a simple locking plate (Fig 1453) When properly applied t

FIG 1449

FIG 1450

Fracture of the necks of the metatarsals with gangrene of the toes to which an important contributory factor was long exposure on the side of a mountain (see page 203). The important point of treatment to be recognised is that local amputation sufficed. Such limited amputation of part of the forefoot, instead of through the "site of election" in the leg, has gained increasing recognition of merit in recent years. This patient made an excellent recovery and flew once again as a pilot within twelve months.

splints do not harm the teeth or gums They are applicable to all except edentulous patients

Dentures, Gunning's splint and circumferential wiring—In edentulous mouths it may suffice to fit the patient s dentures and add the fixation of a firm bandage to the jaw Alternatively the surgeon may use Gunning s splint which is an upper and lower denture joined together by vulcanite blocks

Fig 14 1
Bilateral fractures of the condyles and fracture of the symphysis immobilised by cap splint

or metal rods to form one piece But these methods are not always successful in preventing redisplacement and if the fracture unites with deformity it may be impossible for the patient to wear dentures with comfort The method of circumferential wiring of the mandible and denture was therefore introduced On the posterior fragment three-quarters of an inch from the fracture line a point is marked on the buccal sulcus at the reflection of gum to cheek A Reverdin needle or trocar and cannula is passed close to the bone emerging through the skin at the lower border of the mandible Stainless steel wire 0·5 mm in diameter is guided through the cannula and pulled into the mouth The cannula is withdrawn At a corresponding point of the reflection of mucous membrane from the gum to the floor of the mouth the instrument is passed against the lingual surface of the bone to emerge through the same skin perforation The other end of the wire is

PART V

INJURIES OF THE TRUNK

brought into the mouth. The wire is then sawed through the tissues until it lies in close contact with the mandible. In a similar manner two other wires are passed, one three-quarters of an inch in front of the fracture line and one on the opposite side of the jaw. The patient's denture or a specially made vulcanite or acrylic plate is placed in position, the fracture is reduced and the three wires are twisted tightly over the plate (Fig. 1455).

FIG. 1455

Fracture of an edentulous mandible immobilised by Gunning's splint with circumferential wiring.

External pin fixation by two-pin splint.—The two-pin splint is an application of the technique first devised by veterinary surgeons and applied by Roger Anderson and Haynes to the treatment of fractures of the shafts of long bones. It consists of a pair of two-pin units, one unit fixed in each fragment and secured to each other by means of a connecting rod.[1,8] The upper and lower borders of the mandible and the line of fracture are marked on the skin with Bonney's blue ink. An assistant holds the posterior fragment firmly. Near its lower border, *one inch* from the fracture line, a pin is drilled obliquely into the bone at an angle of 60 degrees. A second pin is then driven in, crossing the first at an angle of *30 to 45 degrees*. Another pair of pins is similarly drilled obliquely into the other fragment of the fractured bone. Universal clamping joints are attached firmly to the pins and the connecting

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Rushton, M. A., Walker, F. "Mandibular Fractures treated by Pin Fixation." *Amer. J. Orthodont.*, 194-, 28, 30.
Mowlem, R., Barron, J. D., MacGregor, A. B., and Barron, J. "External Pin Fixation for Fractures of the Mandible." *Lancet*, 1941, 2, 391.
Mowlem, R. "Fixation Methods from the Standpoint of the Plastic Surgeon." *Brit. dent. J.*, 1941, 71, 323.
Mowlem, R. "Skeletal Fixation in Fractures of the Jaws." *Proc. R. Soc. Med.*, 1942, 35, 415.
Peid, L. "Extra-oral Splinting of the Edentulous Mandible." *Lancet*, 1941, 2, 354.

rod is loosely attached The fracture is reduced the clamps on the connecting rod are securely tightened and the fragments are thereby immobilised in the reduced position (Fig 1456) Many surgeons favour the substitution of a single pin of stouter calibre in place of the cross pin unit Some single pins are threaded

Complications—The complications of fracture of the mandible include sepsis mal union non union and trismus The incidence of bone infection has been greatly reduced by the use of penicillin and other antibiotics *Nevertheless surgical intervention with drainage of abscesses and removal* of dead teeth and bone is sometimes required *Mal union* from failure of early treatment may cause imperfect occlusion and need extraction of teeth with the fitting of dentures More serious deformity including mandibular protraction and retraction should be treated by osteotomy and immobilisation in the corrected position [1] *Non union* is usually due to extensive loss of bone with infection and imperfect immobilisation When quiescence of infection has been secured a broad flat graft is cut from the crest of the ilium and laid across the gap in contact with at least one inch of rawed bone on each fragment [2,3] Fixation may be secured by cap splints or one of the methods outlined above Internal fixation by wires or screws should not be used because there is danger of recurrent infection For the same reason the graft should consist only of cancellous bone—not cortical bone When there is infection cortical bone undergoes sequestration and causes persistent delay in union of the fracture This is to be avoided by using only cancellous bone chips If reliable fixation is achieved by splints the fracture unites even if slight infection recurs A wait of many months is therefore unnecessary before the grafting operation—it may be undertaken within a few weeks of healing of the wound *Trismus* may follow fracture-dislocation of the condyles or compound comminuted fractures of the rami It is sometimes necessary to use cap splints on the upper and lower teeth fixed with a screwing device by which the jaw can be opened gradually and physiotherapy

FIG 1456

Double fracture of the mandible immobilised by two-pin splints, one on each side of the jaw

Hensel, G. C. [illegible] of Mandibular Protraction and Retraction." *Surgery* 1937, 2, 92. St Louis.
Babbington, W. and [illegible] H. Bone Grafting of the Mandible *Brit. J. Surg.* 1948, 12, 49
Harkins, H. N. and Phemister, D. B. Onlay Grafts for Fracture of the Mandible *J. Amer. med. Ass.* 1937, 109, 1501

CHAPTER XXX

FACIO-MAXILLARY INJURIES

The reconstructive surgery of disfigurements and deformities of the face is the special duty of plastic surgeons—but every surgeon in a casualty service or an orthopædic and accident department must be ready to undertake the emergency treatment of wounds of the face as well as the primary treatment of fractures of the mandible maxilla and facial bones [1-7] In this field of surgery great progress has been made in recent years especially from the impetus of the last great war when so many of these injuries were sustained from bomb and shell explosions and the crash of aircraft as well as from motor collisions and industrial injuries In every field of surgery there is need for close co-operation between specialists but nowhere is this more obvious than in the management of facio-maxillary injuries Casualty surgeons must be ready to accept the responsibilities of the emergency treatment of wounds of the face and the first steps in treating facio-maxillary fractures before transferring patients with these injuries to the special departments of facio-maxillary and plastic surgery *

Emergency treatment of facial wounds—The face should be washed—grease dirt and oil being removed with ether and detergent solutions It may be wise to cut the hair short but there is no need for complete shaving, and it is better not to shave the eyebrows or the margin of the scalp where the hair line serves as a guide for accurate replacement of skin flaps The danger of pigmentation of scars from ingrained dirt should be prevented by gently scrubbing the tissues with a soft tooth brush removing more adherent particles with the point of a scalpel The blood supply of the tissues of the face is so good, and the resistance to infection is so high that there is no need for free excision of the skin such as may be required in wounds of the limbs Only the very lightest trimming of completely crushed and dead parts of the skin margin is needed After a restrained and conservative excision the wound should be sutured with the finest possible nylon or thread preferably mounted on eyeless needles Many stitches should be introduced as closely as possible to the margin of the skin rather than a few stitches being inserted boldly and bluntly at a distance from it

* I am grateful to Mr John Boyes of Edinburgh who has written most of this chapter

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2 James, W Warwick, & Fickling, B. W "Injuries of Jaw and Face" London John Bale and Staples Ltd., 1943.
3 Fry W Kelsey and others. "Dental Treatment of Maxillo-facial Injuries. Oxford Blackwell Scientific Publications Ltd., 1942.
4 Thoma, Kurt H "Traumatic Surgery of the Jaws. London Henry Kimpton. St Louis C V Mosby Co., 1942.
5 Manual of Standard Practice of Plastic and Maxillo-facial Surgery Philadelphia and London W B. Saunders Company (Military Service Manuals, 1 194).
6 Report on Maxillo-facial Injuries. J R Army med. Cps., 1930, 87 31
7 Cole P P War Injuries of the Face and Jaw" War Wounds and Injuries. Edited by E. Fletcher and R W Brewer London Edward Arnold & Co 1940.

DISLOCATION OF THE MANDIBLE

Vhen the mouth is opened widely the head of the mandible on each side s forwards into an unstable position on the eminentia articularis A ively light blow on the chin may then cause bilateral dislocation The lacement sometimes occurs from the pull of the pterygoid muscle during ning and vomiting or while taking an unusually wide bite Unilateral ocation occasionally follows the unskilful use of a mouth gag

Clinical features—The mouth is held rigidly open with the jaw projecting ards in bilateral dislocation and towards the uninjured side in unilateral ocation Swallowing and articulation are difficult and saliva dribbles 1 the mouth The head of the mandible may be felt in front of its usual tion with a hollow behind it at the level of the tragus

Treatment—The operator should stand in front of the patient and with protected thumbs passed into the mouth press the angles of the jaw nwards, at the same time raising the chin with his fingers outside the ith As a rule the displacement is corrected easily without anæsthesia he dislocation is of longer standing and there is unusual difficulty pieces ork may be placed between the molar teeth on which the jaw can be ered when the chin is elevated. A bandage which elevates and supports chin is kept in position for ten or fourteen days A four tailed bandage ich pulls the chin backwards should be avoided.

Unreduced dislocation of the temporo-mandibular joint—If a dislocation of temporo-mandibular joint has been left uncorrected for more than about or fourteen days replacement by manipulation is difficult or even possible Operative reduction may be needed perhaps even with excision the condyles but before embarking on such a plan of treatment the geon should remember that useful movement and good function is netimes regained despite failure of reduction. This is discussed more ly in the next section where fracture-dislocations of the temporo-mandibular nt are considered.

Recurrent dislocation of the temporo-mandibular joint—Recurrent location is a distressing condition despite the fact that the patient is en able to reduce the displacement himself. It is often enough to instruct patient to avoid wide-open bites and arrange for his dental surgeon to that there is accurate occlusion of the teeth. Sometimes injection into joint of a sclerosing solution such as sodium psylliate may be needed order to promote fibrosis and contraction of the capsule

CLICKING OF THE TEMPORO-MANDIBULAR JOINT

Minor displacement of the temporo-mandibular joint short of actual location but associated with a clicking or grating noise is a common ability which usually arises from forward slipping of the head of the andible over the margin of a loose temporo mandibular meniscus Excessive obility of the meniscus is of course aggravated when there is inaccurate clusion of the teeth especially when the molar teeth are missing and food chewed with the front teeth alone As with subluxation and recurrent

dislocation the disability is aggravated by wide-open bites of large crusts of bread or lumps of apple and nearly always it can be relieved if this is avoided It may sometimes be wise to inject the joint with sodium psylliate In exceptional cases the joint may be immobilised for two or three weeks by wiring the teeth of the upper and lower jaws together Excision of the meniscus through an incision placed behind the auricle avoiding branches of the facial nerve is needed only when every other measure has failed

FRACTURE OF THE CONDYLE AND FRACTURE-DISLOCATION OF THE MANDIBLE [1]

In fracture-dislocation of the temporo-mandibular joint the head of the mandible is dislocated from the glenoid fossa and it is separated from the condylar process by a fracture of the neck of the mandible The injury is often bilateral and it may be associated with other fractures of the mandible

Treatment—If the fracture-dislocation occurs as an isolated injury successful reduction may be possible by the manœuvre described for simple dislocation If this fails three methods of treatment are available operative reduction excision of the head of the mandible conservative treatment [2,3] No operation on the temporo-mandibular joint is easy because there is vigorous hæmorrhage and it may be difficult to avoid injury to filaments of the facial nerve The dissection needed to expose the displaced head is liable to cut its ligamentous and muscular attachments and by depriving it of blood supply to cause avascular necrosis Finally, unless the whole auricle is reflected forwards by an incision behind it a facial scar is inevitable It is also to be recognised that the results of non-operative treatment are surprisingly good even when reduction fails (Figs 1457 1460) Some surgeons recommend the insertion of a pin into the small condylar fragment so that it can be controlled more directly and be replaced more certainly Once this has been achieved the pin is incorporated in a pin fixation device This however is a very difficult procedure Usually the best treatment is to attempt manipulative reduction and, whether it succeeds or not to support the jaw with the teeth in accurate occlusion by means of bandage or cap splints and to permit active mobilisation within two or three weeks Any tendency to lateral deviation of the jaw may be controlled even after mobilisation has begun by fitting a cap splint on the lower teeth with a flange against the upper teeth on the opposite side If the resulting range of movement proves to be unsatisfactory or painful late excision of both mandibular heads can be considered

Summary of the treatment of mandibular fractures—

1 *Teeth in both fragments of lower jaw and in upper jaw*—Cap splinting or interdental wiring

2 *Teeth in both fragments of jaw with loss of substance*—Through and through drainage and interdental wiring until cap splints are made

3 *Teeth in both fragments of lower jaw but absent from upper jaw*—Cap splinting with upper denture for occlusion or two pin splint

Walker D G Fractures of Ramus and Coronoid Process of the Mandible " *Brit dent J*, 1947 72, 463 [illegible]
Kapple, M Fracture-dislocation J w (advocating operative replacement). *Zbl. Chir* 1941 61 14
Stromberg, Y Fracture-dislocation J w (advocating excision of the head). *Acta chir scand* 1941 74, 579

CHAPTER XXX

FACIO-MAXILLARY INJURIES

The reconstructive surgery of disfigurements and deformities of the face is the special duty of plastic surgeons—but every surgeon in a casualty service or an orthopaedic and accident department must be ready to undertake the emergency treatment of wounds of the face as well as the primary treatment of fractures of the mandible maxilla and facial bones[1-7] In this field of surgery great progress has been made in recent years especially from the impetus of the last great war when so many of these injuries were sustained from bomb and shell explosions and the crash of aircraft as well as from motor collisions and industrial injuries In every field of surgery there is need for close co-operation between specialists but nowhere is this more obvious than in the management of facio-maxillary injuries Casualty surgeons must be ready to accept the responsibilities of the emergency treatment of wounds of the face and the first steps in treating facio-maxillary fractures before transferring patients with these injuries to the special departments of facio-maxillary and plastic surgery *

Emergency treatment of facial wounds—The face should be washed—grease dirt and oil being removed with ether and detergent solutions It may be wise to cut the hair short but there is no need for complete shaving and it is better not to shave the eyebrows or the margin of the scalp where the hair line serves as a guide for accurate replacement of skin flaps The danger of pigmentation of scars from ingrained dirt should be prevented by gently scrubbing the tissues with a soft tooth brush removing more adherent particles with the point of a scalpel. The blood supply of the tissues of the face is so good, and the resistance to infection is so high that there is no need for free excision of the skin such as may be required in wounds of the limbs Only the very lightest trimming of completely crushed and dead parts of the skin margin is needed After a restrained and conservative excision the wound should be sutured with the finest possible nylon or thread preferably mounted on eyeless needles Many stitches should be introduced as closely as possible to the margin of the skin rather than a few stitches being inserted boldly and bluntly at a distance from it

* I am grateful to Mr John Boyes of Edinburgh who has written most of this chapter

Ivy, R. H. and Curtis, L. "Fractures of the Jaw." London Henry Kimpton, 1938.
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4 *Teeth in anterior but not in posterior fragment of lower jaw*—Cap splints or interdental wiring with a gutta percha mould pressing on the edentulous fragment or a two pin splint or wire traction on the posterior fragment to a rod connected with a plaster head cap

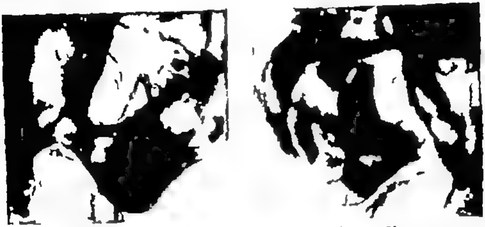

Fig 1457 Fig 1458

Bilateral fracture-dislocation of temporo-mandibular joints with a comminuted fracture of the body of the mandible—left and right oblique views.

Fig 1459 Fig 1460

Same case as that shown in Figures 1457 and 1458 showing the *free range of painless* movement which may develop despite failure to reduce the fracture-dislocation.

5 *Edentulous mandible and edentulous maxilla*—Gunning s splint circumferential wiring or two pin splint

6 *Fracture of ramus*—Immobilise for short period by cap splints with lock pin or interdental wiring or Gunning s splint

7 *Fracture of condyle and fracture-dislocation of jaw*—Permit early movement but prevent lateral deviation of the jaw by cap splint on lower teeth with flange against upper teeth on the opposite side

Such skin sutures cause far greater disfigurement than the scar of the original wound—and this is of course a general principle applying not only to the face but to wounds everywhere. I am astonished by the readiness of some surgeons to disfigure patients by the use of thick skin sutures inserted so widely and tied so tightly that cross scars are produced.

Treatment of full thickness loss of skin—In penetrating wounds of the face when there has been loss of the whole thickness of the cheek with destruction of bone, the mucous membrane of the buccal surface should be sutured to the margins of the skin in such a way that the fractured surface is covered. After healing of the wound and control of infection the soft tissues will be reconstructed by plastic repair and the defects in the bone will be made good by grafting.

Problem of extraction of teeth—The decision as to whether or not to extract teeth at the time of the emergency operation should be based on the two principles: 1) even damaged and injured teeth may be useful for immobilisation of the bones during early weeks and months; 2) dead carious and loose teeth cause infection and act as sequestra. At the time of the emergency operation no teeth should be removed except those that are completely loose. Shortly thereafter infected teeth may need to be extracted in order to control infection of mandibular or maxillary fractures. Meanwhile the essential points are that teeth are used for the attachment of wires and splints in the immobilisation of fractures and that even a single tooth remaining on one fragment may be of the greatest value.[1, 4]

Emergency treatment of fractures of the jaw with respiratory obstruction—In many mandibular and facio-maxillary injuries there may be respiratory obstruction from approximation of the swollen tongue and palate to the posterior pharyngeal wall. A Magill naso pharyngeal tube lubricated with percaine ointment should be inserted through the nostril with continuous gentle pressure until it passes the obstruction. When it is safely passed the patient at once experiences great relief and he is allayed of anxiety; the shock is relieved.[5]

Preventing infection—In the emergency treatment of all facial wounds and fractures of the mandible and maxilla it is wise to anticipate the possibility of infection by giving penicillin or other antibiotics. Such chemotherapy should be continued throughout the period of immobilisation, together of course with careful toilet of the teeth and antiseptic irrigations of the mouth.

Immobilisation of injured tissues—Immobilisation not only promotes the union of fractures but also assists the healing of soft tissues: it prevents the spread of infection and controls the development of deformity. While the surgeon is engaged in excising and suturing the wound and reducing the displacement of fragments, the dental surgeon takes impressions of the teeth and subsequently prepares, fits and adjusts the splints. If skilled dental assistance is not available three simple methods of immobilising the jaw may be used: 1) the patient's dentures may be put in position with

Kelsey Fry, W. "Fractures of the Mandible." *Proc. R. Soc. Med.* (Section of Odontology), 19[illegible], 22, 667.
James, W. W. & Fickling, B. W. "Injuries of the Jaw and Face." London: John Bale and Staples Ltd., 1942.
Parfitt, G. J., Mackie, I. A. C., and Shepherd, P. R. "Teeth in the Line of Fracture." *Brit. dent. J.* 19[illegible], 73, 23.
Greer Walker, D. "Should Teeth in the Line of Fracture be Removed?" *Proc. R. Soc. Med.* (Section Odontology), 194[illegible], 35, 664.
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CLASSIFICATION OF FACIO-MAXILLARY FRACTURES

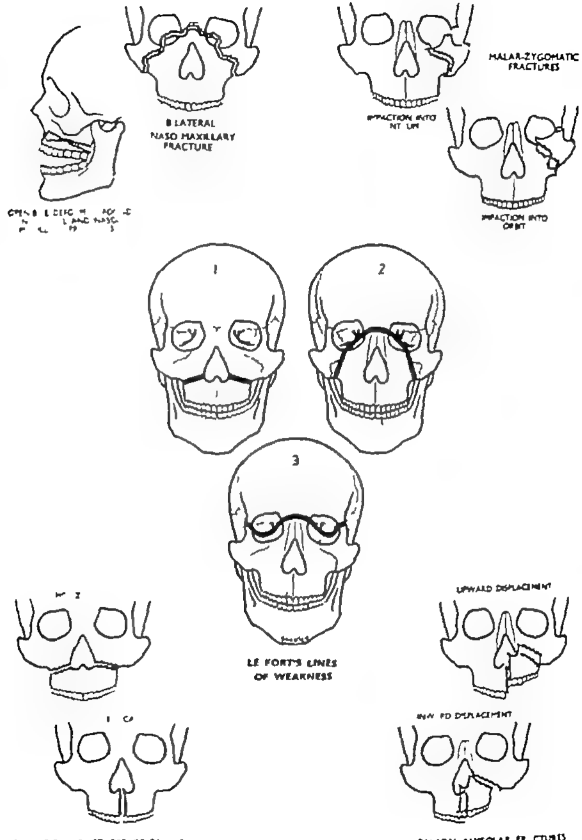

Fig. 1461

the jaw firmly supported by means of a suitable bandage 2) the lower denture may be fixed to the mandible by circumferential wiring, 3) the teeth in the upper and lower jaws may be ligatured to each other by interdental wiring In bandaging the jaw it is important to secure vertical support, and to avoid the backward pull of a four tailed bandage which is liable to cause receding of the jaw and mal union of fractures

FRACTURES OF THE MANDIBLE

If the jaw is struck while the teeth are clenched the mandible usually escapes fracture because the force is transmitted directly to the skull and to the powerful muscles of the neck—but if the jaw is in the normal position of rest and the teeth are slightly apart similar violence is likely to fracture the bone A blow on the point of the chin may cause bilateral fractures of the condyles A very strong blow may also split the body of the mandible near the symphysis Injuries to the lateral aspect of the jaw tend to fracture the bone at the site of impact and near the canine region on the opposite side Fractures of the angle of the jaw, the ascending ramus and the coronoid process are less frequent [1]

Displacement of mandibular fractures—The fragments of a fractured jaw may be displaced by the initial violence, the deformity being increased by muscle traction Muscles attached to the body of the bone pull downwards whereas muscles attached to the ramus pull upwards In a bilateral fracture of the body of the mandible the chin fragment is therefore depressed In a unilateral fracture near the posterior part of the body the posterior fragment is rotated upwards

Clinical features—There is local swelling with bruising and deformity often with dribbling of blood-stained saliva from the open mouth fetor of breath and difficulty in articulation and swallowing Anæsthesia of half the lower lip points to a fracture crossing the inferior alveolar canal behind the mental foramen Movement of the jaw is restricted There may be deviation to one side irregularity of the teeth and abnormal occlusion with the teeth of the upper jaw Bruising of the mucosa of the cheek, gums and floor of the mouth indicates a fracture of the body In the edentulous mandible displaced fractures of the body are usually compound into the mouth Bruising of the tonsillar pillars of the lower part of the soft palate and of the lateral pharyngeal wall suggest a severe fracture of the vertical portion of the bone The diagnosis is confirmed by radiographic examination which should include three standard views—postero-anterior skull right lateral mandible and left lateral mandible Additional projections which may be of value include lateral views of the tempero-mandibular joint with the mouth open and the mouth closed dental and occlusal views and the 30 degrees oblique view or Stenver s projection

Methods of immobilisation—The mandible may be immobilised 1) when teeth are present by interdental wiring or cap splints 2) when the jaws are edentulous by the patient s dentures Gunning s splint or circumferential wiring 3) by two pin skeletal transfixion splint (Fig 1451)

[1] McIndoe A H, "Surgical and Dental Treatment of Fractures of the Upper and Lower Jaws in War Time. Review of 119 Cases. *Proc R Soc Med* (Section of Odontology), 1941 34 [illegible]

CLASSIFICATION OF FRACTURES OF THE FACIAL BONES

The framework of the face consists of a series of bone plates which with the exception of the malar and palatal areas are thin and fragile It is suspended from the skull by four vertical plates (the medial and lateral orbital walls) together with the zygomatic arches pterygoid plates and lateral orbital margins These bones are intimately connected as a complete facial skeleton and injuries should therefore be classified as fractures of regions and not as fractures of individual bones

1 Fractures of the naso-maxillary unit
   i) Nasal fractures
   ii) Bilateral naso maxillary fractures

2 Fractures of the malar maxillary unit
   i) Impacted fracture of the malar
   ii) Comminuted fracture of the zygomatic arch

3 Fractures of the palatal unit
   i) Horizontal separation of the palate
   ii) Mid line separation of the palate
   iii) Palatal-alveolar fractures

FRACTURES OF THE NASO-MAXILLARY UNIT

Nasal fractures—Deformity from fracture of the nasal bones and cartilages is of four types according to the direction of violence and the site of the blow (Fig 1462) 1) When an anterior force strikes the nose near the glabella the nasal bones and adjacent nasal processes of the maxillæ are driven into the cavity of the nose the upper part of the septum and the ethmoid are damaged and the bridge of the nose is depressed In profile the fronto-nasal angle is lost and the tip of the nose is rotated upwards As seen from the front the nostrils are abnormally conspicuous 2) When the blow is sustained near the middle of the ridge at the junction of bone and cartilage the nasal bones are separated at the mid line and driven back with their lateral margins overlapping the nasal process of the maxillæ so that the deformity includes not only flattening of the bridge of the nose but also broadening of the base 3) A blow at a still lower level causes fracture of the bony or cartilaginous part of the septum or dislocation of the septum from its bone ridge on the vomer or from its attachment to the columellar cartilage Dislocation from the columella gives rise to an obvious ridge within the nostril due to the displaced sharp septal margin 4) Lateral violence displaces the nasal ridge to the side towards which the force was travelling and gives rise to an S-shaped deformity The nasal bone which receives the blow is flattened its anterior margin being impacted beneath the opposite nasal bone which lies more vertically

Treatment—Profuse hæmorrhage may make it necessary to plug the nose as a first-aid measure—the plugs should be removed as soon as possible and indeed they should not be used at all if there is cerebrospinal rhinorrhœa The deformity should be reduced under anæsthesia Simple manipulation

METHODS OF IMMOBILISING FRACTURES OF THE MANDIBLE

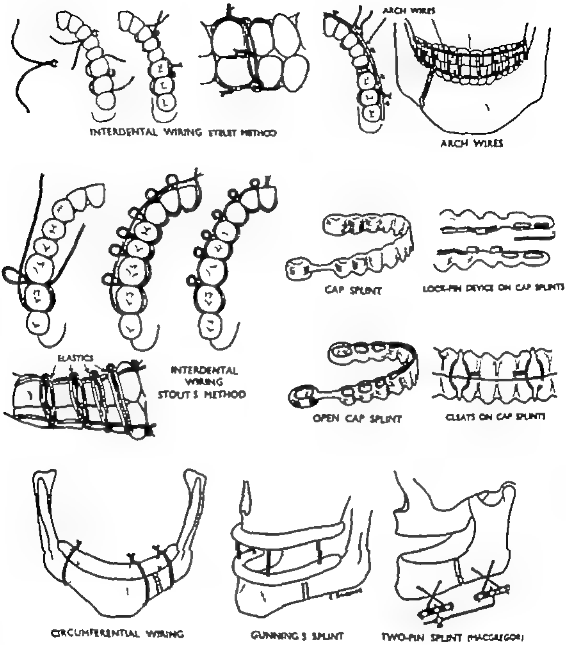

FIG 1451

When there are teeth in both fragments, a fracture may be immobilised by interdental or arch wiring, or still better by cap splints. When the jaw is edentulous, Gunning's splint, circumferential wiring or the two-pin splint is used.

Interdental wiring—Non-corrosive steel ligature wire should be used A five-inch length is doubled round the closed points of hæmostat forceps and twisted to form a small central eyelet Both ends of the wire are passed through the dental interspace selected leaving the eyelet on the labial side The two ends are then brought back through the next interspaces on each side and twisted tightly together below the eyelet in the upper jaw and above the eyelet in the lower jaw Several pairs of ligatures are fixed in the upper and lower jaws directly opposite each other or in oblique

with the fingers may suffice to correct lateral displacement but if there is impaction of the fragments or depression of the bridge of the nose forceps are necessary Ash s forceps are inserted with one blade on each side of the septum so that the deviation of the septum is corrected and the bridge of the nose elevated Long bladed forceps (Walsham s forceps) protected with rubber tubing with one blade inside and one outside the nose are then used to correct the position of the nasal bones When the deformity is completely corrected, reduction is often stable without external support but it may be wise to use small plaster slabs one inch by three inches or to apply lateral pressure by gutta percha moulds fixed to a plaster head piece If intranasal support is needed padded finger cots may be inserted in the nostrils for about twenty four hours Occasionally a special intranasal splint is required

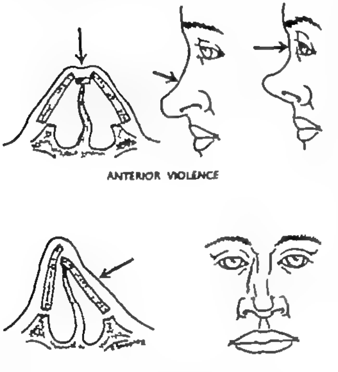

Fig. 1462

Nasal fractures due to anterior violence cause depression of the nasal bridge ; lateral violence causes an S-shaped deformity

Bilateral naso maxillary fractures — These fractures follow the second line of weakness described by Le Fort (Fig 1461) The maxilla is displaced backwards between the malar bones thus causing mal-occlusion of the teeth The upper teeth lie behind the lower and there may also be upward rotational displacement of the maxilla so that when the jaws are closed only the molar teeth meet — the open bite deformity There is very extensive bruising and swelling of the face which in early days conceals the deformity Diplopia is common

Treatment—Nasal impaction is corrected by means of Ash s and Walsham s forceps The maxillary block is then gripped with special forceps designed with spikes by which to secure a firm hold of the alveolar bone [1] The bone is rocked until impaction is released Reduction of the fracture is maintained by a maxillary cap splint cemented to the teeth and fixed by means of a rod and universal joint (Walker Clouston joint) to a plaster head cap [2] (Figs 1465-1467) Mowlem has used cheek wires attached to the mandibular and maxillary teeth and passing through the substance of each cheek to a plaster head cap [3] (Fig 1465)

[1] McIndoe A. H "Diagnosis and Treatment of Injuries Middle Third of Face " *Brit dent J* 1941 71 235
[2] Mowlem, R. "Fixation Method from the Standpoint of the Plastic Surgeon," *Brit dent J* 1941 71 [illegible]
[3] Mowlem, R "Experiences with various Methods of Skeletal Fixation in Fractures of the Jaws" *Proc R. Soc Med* (Section of Odontology) 1942, 35, 41[illegible]

FRACTURES OF THE MALAR-MAXILLARY UNIT

Impacted fractures of the malar bone and comminuted fractures of the zygomatic arch[1] are sustained from direct violence A violent blow on the cheek may be sustained in a motor accident or more simply during a game of football from the impact of another player's head The lines of fracture correspond fairly closely with the articulations of the bone except that the lower fracture line passes through the malar process of the maxilla which is included in the displacement The malar prominence and side of the face are thus flattened although the deformity is often concealed by swelling and hæmorrhage The lateral wall of the antrum is broken and the sinus fills with blood There is often bleeding from the nose Opacity of the antrum is shown in radiographs and by transillumination of the face The fracture line usually involves the inferior orbital canal and there may be an area of anæsthesia of the face from injury to the infra-orbital nerve The superior alveolar nerves may also be injured The roof of the antrum is fractured and sinking of the lower and outer part of the orbit causes diplopia Depression of the zygomatic arch interferes with movement of the coronoid process so that it is difficult to open and close the mouth (Fig 1463) The mandible may swing to the opposite side and cause mal-occlusion of the teeth

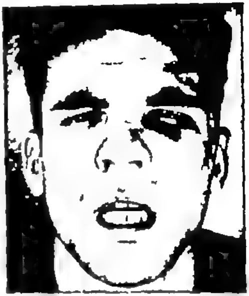

FIG 1463

Depressed fracture of the malar with locking of the jaw Although photographed within three hours of accident, the deformity is already masked by swelling and ecchymosis.

Treatment—The malar bone should be elevated as soon as possible The hair of the temporal region is shaved and an incision about one inch in length is made within the hair margin anterior and parallel to the superficial temporal vessels The deep temporal fascia is divided and a long lever such as a periosteum elevator or a Kilner's malar lever is passed through the substance of the temporal muscle until it lies beneath the body of the bone A small rolled bandage is used as a fulcrum under the lever and the malar is disimpacted and elevated (Fig 1464) The instrument should be passed under all parts of the bone from the zygoma to the orbit and down to the lower

FIG 1464

Same case as Figure 1463 ten days after replacement of the bone showing the scar within the hair margin and the technique of operation.

[1] Gillies, H. D., Kilner T Pomfret, and Stone D "Fractures of the Malar Zygomatic Compound." *Brit. J Surg.*, 1928, 14 651

impact of the steering column against the front of the driver's chest [1,2] The junction of the mobile body of the sternum with the relatively fixed manubrium sterni is the usual site of injury and there is backward displacement of the body sometimes with over riding of the fragments Lateral and oblique radiographs taken in the position of inspiration show the injury (Fig 1460) The spine should be hyperextended by pillows beneath the upper dorsal spine The fracture usually unites very quickly (although there have been one or two cases of non union after vertical splitting of the sternum in exposing the thymus gland) Rupture of the internal mammary artery with hæmothorax has been described as a complication

FIG 1460
Fracture of the sternum at the junction of the manubrium with the body which is displaced backwards

FRACTURES OF THE HYOID BONE AND THYROID CARTILAGE

Compression fractures of the thyroid cartilage and hyoid bone are fortunately rare because the mortality may be as high as 75 per cent [3,4] The thyroid cartilage may be crushed against the vertebral column by a blow or be compressed laterally as in hanging and strangling The injury usually occurs in adult men It is very seldom sustained by women whose laryngeal cartilages do not usually ossify The greatest danger is from œdema of the larynx A tracheotomy set should be kept available for about ten days

VISCERAL COMPLICATIONS OF CHEST INJURY

Crushing injuries of the chest may cause 1) traumatic asphyxia 2) pneumothorax from laceration of the lung and bronchi or a punctured wound of the chest wall 3) hæmothorax from laceration of the lung or rupture of the intrathoracic vessels 4) intrapericardial hæmorrhage 5) rupture of the diaphragm and diaphragmatic hernia

Traumatic asphyxia —Compression of the chest arising from crushing injury may force blood back from the heart and intrathoracic veins into the innominate internal jugular and external jugular veins These vessels are not protected by valves so that the smaller veins and venules are distended Blood may also be extravasated into the tissues of the head neck and upper chest thus causing temporary loss of consciousness bleeding from the nose and ears subconjunctival hæmorrhage pigmentation of the

Mock, W G "Fractures of the Sternum." Amer J Surg 1933 22, 206 and 1937 38 560.
Heiserman H H Fracture and Dislocation of the Sternum. J Surg., 1928 [illegible]
Mock, W G Fractures of the Thyroid Cartilage Amer J Surg., 19[illegible] 38, 462.
Eklstern, S Fracture of Hyoid Bone " Ann. Surg 1934 99, 34

margin It is often unnecessary to use post-operative support but if the bone tends to redisplace when the lever is removed the antrum should be packed The gum mucosa is incised behind the canine tooth and through a small antrostomy the cavity is packed lightly with one-inch ribbon gauze soaked in pigmentosa iodoformi compound (Whitehead's varnish) the malar bone being held meanwhile in the corrected position The end of the ribbon gauze is left lying free in the incision made in the mucous membrane Alternatively the reduction may be maintained by passing a wire through the orbital angle of the malar and attaching it to a rod fixed to a plaster head piece [1]

FRACTURES OF THE PALATAL UNIT

Horizontal separation fracture of the palate—This injury known as Guerin's fracture closely follows the first line of maxillary weakness described

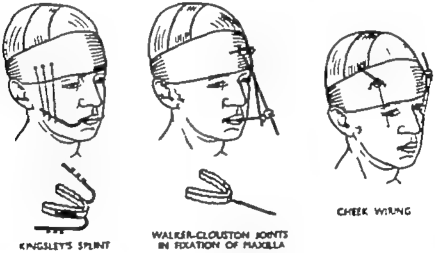

FIG 1465

Methods of immobilising the maxilla.

by Le Fort A severe blow centred near the nasal spine separates the palate and drives it backwards The upper incisors bite behind the lower and there may also be rotational displacement causing an open bite deformity The displacement is reduced by gripping the maxilla on each side at the alveolar margin with special forceps rocking the bone until it is disimpacted and replacing it in accurate occlusion with the mandibular teeth Reduction is maintained by a cap splint connected to a head cap with universal joints The Kingsley splint shown in Figure 1465 was used by military surgeons in recent wars but although it can be applied rapidly it is difficult to maintain a balance between the traction on the two sides and it has now been largely superseded by other methods

Vertical separation fracture of the palate—The clinical diagnosis of mid line separation of the palate is obvious because there is a visible split in the mucous membrane of the roof of the mouth mal-occlusion of the teeth and a wide gap between the central incisors First-aid treatment consists

[1] Gerrie J W "Fracture of the Maxillary Zygomatic Compound." C and med. Ass. J., 193 xx 22, 155.

FIG. 1470

Traumatic asphyxia

A crushing chest injury drives blood from the chest into the veins of the neck and head, thus causing sudden distension of venules and extravasation of blood into the conjunctivae and the skin except where it is supported by the pressure of braces, collar and collar stud. The patient was crushed under a motor lorry.

Fig 1466

Maxillary splint with Walker Clouston universal joints.

Fig 1467

Maxillary splint with universal joints showing wire used for traction with Balkan Beam apparatus to bring forward maxilla (it is usually necessary to have a crown piece in plaster head caps—see Fig 1465)

FIG. 1470.—*Before reduction*

The patient with traumatic asphyxia shown in Figure 14[illegible]0 also sustained a disruption of the pelvis.

FIG. 1471.—*After reduction*

The disruption of the pelvis, with dislocation of the right sacro-iliac joint, separation of the symphysis, and fractures of both pubic rami, was corrected by the lateral compression of pelvic slings. This treatment is discussed more fully in the next chapter.

simply in fixing elastic bands to teeth on opposite sides of the upper jaw This often succeeds in reducing the displacement If it fails cap splints should be fitted to the teeth of both maxillæ with a connecting bar across the palate which can be screwed up and shortened One half of the palate

FIG 1468

Bilateral naso-maxillary fracture in the patient shown in Figures 1466-1467 The middle third of the face including nasal bones and maxillæ is thrust backwards between the molar bones. Unless it is held forward by maxillary splints a dish face deformity remains.

is sometimes displaced upwards as well as outwards and after reduction by traction the maxilla must be fixed to the mandible by cap splints with lock pins

Palatal-alveolar fracture—One section of the alveolus is separated and the fragment together with the teeth it carries is driven in towards the palate or displaced in the opposite direction Displacement is reduced by manipulation and fixation is secured by cap splints

skin and often pulmonary congestion with radiographic appearances resembling miliary tuberculosis The skin pigmentation is brick red in colour Owing to its distribution in the face and neck gradually fading out over the upper chest it was described by Ollivier as the *masque ecchymotique* The blood is driven into the tissues by relatively low intravenous pressure and extravasation into the skin is therefore prevented by any external support such as the pressure of braces a collar or even a collar stud On the other hand in the loose subconjunctival tissues where resistance is least extravasation is most pronounced

Traumatic asphyxia may be sustained from crushing of the chest in the panics of a crowd Six patients with this injury were admitted to the Bellevue Hospital New York, after the cry of fire had been falsely raised in a cinema The patient illustrated in Figures 1470 1471 was an airman who was pinned under the framework of an overturned lorry the weight being across the upper abdomen and lower chest He was released within two minutes He recalls a sensation of pressure across the abdomen spreading up as if the blood was being forced to his head Ten minutes later when being lifted into the ambulance he regained consciousness but complained of blurred vision as if looking through a mist A companion noticed that he was breathing heavily and slowly and that his chest was red and his face was turning purple When examined shortly afterwards there was bleeding from both ears with subconjunctival hæmorrhage exophthalmos and œdema of the lids Blurring of vision persisted for three hours Two ribs had been fractured and pulmonary œdema and congestion developed The skin pigmentation gradually faded but without going through the usual colour changes of a bruise it was normal within three weeks The conjunctivæ still showed staining after two months Recovery was complete with no loss of hearing or vision

Open pneumothorax[1 4]—A large wound of the chest wall allows communication between the pleural space and the atmosphere destroys the pleural negative pressure and causes collapse of the lung and anoxæmia But this is not the most serious effect of an open pneumothorax *The greatest danger arises from pendulum action of the mediastinum which is sucked to and fro with every respiratory effort* The right side of the heart does not fill normally and a patient with a large sucking wound cannot survive long As a first aid measure the lung should be grasped with any suitable instrument and pulled into the wound of the thoracic wall so that the *pendulum swing of the mediastinum is controlled*

Tension pneumothorax—If a wound of the chest wall or of the lung is valvular so that air enters the pleural cavity on inspiration but cannot be expelled during expiration a tension pneumothorax develops There i increasing intrapleural pressure with displacement of the heart and mediastinal structures to the opposite side and pressure on the right side of the heart and great veins as well as increasing dyspnœa and cyanosis These are urgent indications for aspiration of air from the pleural cavity A short wide bore needle should be inserted through the second intercostal space two inches from the margin of the sternum and connected to a tube

Tudor Edward A Treatment of Injuries of the Chest *Brit med J* 1940 ii 1040
Sauerbruch F and O Tanaghuess L Thoracic Surgery London Edward Arnold & Co 193
Butler F Injuries of Chest and Abdomen *Surg Gyn Obstet* 193 66 41
Roland F h Fra [illegible] of Lungs and Pleura [illegible] chest wounds [illegible]
1938 104

CHAPTER XXXI

INJURIES OF THE CHEST

Children and adolescents seldom sustain fractures of the ribs but the risk of this injury increases with advancing years as the chest wall becomes more rigid It should be recognised that the rarity of these fractures in children is the consequence of elasticity and flexibility of the chest wall which obviously increases the danger of injury to the viscera within the chest The degree of internal injury cannot be judged by the injury to the ribs Similarly in adults it is fallacious to assume that a trivial rib fracture cannot be associated with more than a trivial lung injury

FRACTURES OF THE RIBS

Mechanism of injury—A direct blow from a fall against the edge of a table or the side of a bath may produce a crack fracture of the exposed parts of the ribs in front of the mid axillary line Crushing injuries seldom fracture the ribs at the site of violence More commonly the ribs give way at the point of maximum convexity in the region of the costal angle The first and second ribs are often protected by the clavicle, and the eleventh and twelfth ribs usually escape In more severe cases however the whole thoracic framework may be crushed several ribs may show double fractures and there may also be fractures of the clavicle and of the lumbar transverse processes Fractures of the ribs have been reported from simple strain of muscles [1 2] Violent sneezing and coughing is sometimes responsible especially in severe tracheitis and in whooping cough The injury can be sustained from the simple effort of lifting heavy loads from the strains of childbirth or even from the exertions of golf and other games

Symptoms—There is pain at the site of injury tenderness on pressure and pain on antero-posterior compression of the chest Respiratory movements are short and shallow Patients are usually more comfortable when sitting than when lying The intercostal tissues provide a considerable degree of immobilisation and union is usually rapid. Callus forms within ten or twelve days There may not be radiographic evidence of consolidation of the fracture until several months after injury but functional recovery is usually complete within a month or six weeks

Treatment—During the first week or two aggravation of the pain from respiratory movement may be relieved by strapping Long strips of

Palfrey, F W "Fractures of Ribs" (ten cases due to coughing). *Boston med surg. J.*, 1924 191, 496
Jones, H E "Rib Fracture produced by Sneezing. *Glasg med. J.*, 1907 67 204.
Kleiner, F R. "Fracture of Rib by Muscle Action" (review of fifty-six reported cases). *Boston med surg J.*, 1924 190 1034

which passes under sterile water in a bottle below the level of the bed, thus allowing escape of air but preventing its re-entry The needle and tube are left in position until air no longer bubbles through the fluid, showing that the communication between pleura and lung is closed

Subcutaneous and mediastinal emphysema—A tension pneumothorax may cause subcutaneous emphysema from the mechanical effect of muscular activity forcing air through a tear in the parietal pleura The emphysema may extend as far as the scrotum and upper thighs Mediastinal emphysema may develop from a tension pneumothorax with rupture of the mediastinal pleura or from rupture of a primary bronchus or the trachea Air is then forced into the mediastinum and the emphysema spreads to the upper chest neck and face

Hæmothorax—Hæmothorax may be due to laceration of the lung or rupture of the intercostal or mammary vessels In the pulmonary arteries the blood pressure is no more than a quarter the pressure of the systemic circulation spontaneous arrest of hæmorrhage is therefore much more likely after laceration of the lung than after laceration of systemic arteries The level of blood in the pleural cavity must be closely observed If it does not rise above the nipple line there is no serious embarrassment but if despite conservative treatment bleeding persists it is probable that the internal mammary or one of the intercostal vessels is torn and operative intervention is necessary In non progressive hæmothorax the blood should be aspirated after three or four days in order to prevent infection It should be removed slowly and be replaced by an equal quantity of air in order to prevent sudden re-inflation of the lung with recurrent hæmorrhage

Hæmoptysis after fracture of the ribs and crushing injury of the chest is usually due to rupture of small pulmonary vessels by the contusion It does not necessarily indicate penetration of the lung by rib fragments

Empyema—When injury of the lung is associated with pleural effusion and hæmothorax there is usually a febrile reaction for several days A temperature of 100° or 101 F does not necessarily mean that there is an *empyema* The effusion should be aspirated on alternate days suitable measures of chemotherapy being arranged

Wounds of the heart[1] causing effusion of blood into the pericardium with rising intrapericardial pressure and cardiac tamponage is to be recognised by the three classical signs 1) muffling of the heart sounds 2) falling blood pressure 3) rising venous pressure If the intrapericardial pressure exceeds 200 mm there is cardiac embarrassment and increasing pressure causes death The pericardium should be exposed to the left of the sternum between the third and fourth costal cartilages The pleura is retracted the pericardium opened and the wound sutured

[1] Griswold, R. A., and Maguire C. H "Penetrating Wounds of the Heart and Pericardium." *Surg Gyn. Obstet.*, 1942, 74, 406.

simply in fixing elastic bands to teeth on opposite sides of the upper This often succeeds in reducing the displacement If it fails cap splint should be fitted to the teeth of both maxillæ with a connecting bar across the palate which can be screwed up and shortened One half of the pala

Fig 1468
Bilateral naso-maxillary fracture in the patient shown in Figures 1466-1467 The middle third of the face including nasal bones and maxillæ is thrust backwards between the molar bones. Unless it is held forwards by maxillary splints a "dish face" deformity remains.

is sometimes displaced upwards as well as outwards and after reduction by traction the maxilla must be fixed to the mandible by cap splints with lock pins

Palatal alveolar fracture—One section of the alveolus is separated and the fragment together with the teeth it carries is driven in towards the palate or displaced in the opposite direction Displacement is reduced by manipulation and fixation is secured by cap splints

CHAPTER XXXII

INJURIES OF THE PELVIS

Fractures and dislocations of the pelvis may be divided into three groups 1) avulsion fractures from muscular violence 2) fractures and dislocations of the pelvic ring from crushing injuries and 3) injuries of the sacrum and coccyx

AVULSION FRACTURES OF THE PELVIS

Sudden and uncontrolled effort may detach any of the muscles arising from the pelvis and avulse fragments of bone from their sites of origin The powerful, long bellied muscles of the thigh are most commonly involved

Anterior inferior iliac spine—*Avulsion of the rectus femoris*—A boy playing rugby football whose enthusiasm is greater than his strength is determined to convert a try however difficult the angle and however distant the posts at the moment of kicking the ball he feels sharp pain in the groin and falls to the ground active flexion of the hip is found to be painful and limited Radiographs show slight downward displacement of a fragment of bone from the anterior inferior iliac spine just above the margin of the acetabulum The bone has been avulsed by the rectus femoris muscle (Fig 1472) This fracture is to be distinguished from the epiphysial line of a separate ossicle of bone which may develop normally in this situation There is no need for operative suture Recumbency for a few weeks with the hip flexed to a comfortable position is the only treatment required

Fig 1472

Avulsion of the anterior inferior iliac spine by the rectus femoris muscle sustained by a schoolboy playing rugby football.

Anterior superior iliac spine—*Avulsion of the sartorius*—Forcible contraction of the sartorius muscle may avulse the bone of the anterior superior iliac spine The fragment is slightly displaced but again there is no indication for operation The pain is relieved by flexion of the hip Even if the displacement is not perfectly corrected functional recovery is usually complete within about two months

CHAPTER XXXI

INJURIES OF THE CHEST

Children and adolescents seldom sustain fractures of the ribs but the risk of this injury increases with advancing years as the chest wall becomes more rigid It should be recognised that the rarity of these fractures in children is the consequence of elasticity and flexibility of the chest wall which obviously increases the danger of injury to the viscera within the chest The degree of internal injury cannot be judged by the injury to the ribs Similarly in adults it is fallacious to assume that a trivial rib fracture cannot be associated with more than a trivial lung injury

FRACTURES OF THE RIBS

Mechanism of injury—A direct blow from a fall against the edge of a table or the side of a bath may produce a crack fracture of the exposed parts of the ribs in front of the mid axillary line Crushing injuries seldom fracture the ribs at the site of violence More commonly the ribs give way at the point of maximum convexity in the region of the costal angle The first and second ribs are often protected by the clavicle and the eleventh and twelfth ribs usually escape In more severe cases however the whole thoracic framework may be crushed several ribs may show double fractures and there may also be fractures of the clavicle and of the lumbar transverse processes Fractures of the ribs have been reported from simple strain of muscles [1 2] Violent sneezing and coughing is sometimes responsible especially in severe tracheitis and in whooping-cough The injury can be sustained from the simple effort of lifting heavy loads from the strains of childbirth or even from the exertions of golf and other games

Symptoms—There is pain at the site of injury tenderness on pressure and pain on antero-posterior compression of the chest Respiratory movements are short and shallow Patients are usually more comfortable when sitting than when lying The intercostal tissues provide a considerable degree of immobilisation and union is usually rapid Callus forms within ten or twelve days There may not be radiographic evidence of consolidation of the fracture until several months after injury but functional recovery is usually complete within a month or six weeks

Treatment—During the first week or two aggravation of the pain from respiratory movement may be relieved by strapping Long strips of

Palfrey, F W "Fractures of Ribs (ten cases due to coughing). *Boston med surg J* 1924, 191 496.
Jones, H E "Rib Fracture produced by Sneezing." *Glasg med. J.*, 1907 67 206.
Kleiner, S. B. "Fracture of Rib by Muscle Action" (review of fifty-six reported cases). *Boston med surg J.*, 1924, 190, 1034

Epiphysis of the ischium—*Avulsion of the hamstrings*—The hamstring muscles arise from the tuberosity of the ischium and a bone fragment may be avulsed by sudden muscular contraction especially in youths whose epiphyses are not united Figure 1473 shows avulsion of the epiphysis of the tuber ischii sustained by a track runner during a hundred yards sprint The track surface was imperfect and the injury was sustained at the moment

FIG 1473
Avulsion of ischium by hamstrings sustained by a track runner

that a slight hollow in the ground called for an increased and unexpected muscular effort There was complete recovery by conservative treatment and the epiphysis united firmly with considerable new bone formation Many of these injuries have been seen in young athletes There is nothing unusual about it and of course there is no need at all for surgical intervention

ISOLATED INJURIES OF THE PELVIC RING

The two innominate bones by their articulation with the sacrum posteriorly and with each other at the symphysis pubis form an intact pelvic ring If a fracture breaks the continuity of this ring at only one level gross displacement of the fragments cannot arise If there is a second injury to another part of the ring considerable displacement of the segment of bone separated by the two fractures may be seen Isolated injuries of the ring include slight separation of the symphysis pubis fractures of the pubic rami fracture of the body of the ilium and subluxation of the sacro-iliac joint—this last being the only serious injury sometimes needing surgical fusion of the joint (Figs 1474-1475)

Fractures of the pubic rami—The most common injury is unilateral fracture of one or both pubic rami Movement of the fragments is limited and displacement is minimal Complete immobilisation is therefore unnecessary The only treatment indicated is recumbency for a few weeks, Recovery should be complete within two to three months

simply in fixing elastic bands to teeth on opposite sides of the upper jaw. This often succeeds in reducing the displacement. If it fails cap splints should be fitted to the teeth of both maxillæ with a connecting bar across the palate which can be screwed up and shortened. One half of the palate

Fig. 1468

Bilateral naso-maxillary fracture in the patient shown in Figures 1466-1467. The middle third of the face including nasal bones and maxillæ is thrust backwards between the molar bones. Unless it is held forwards by maxillary splints a "dish face" deformity remains.

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Palatal alveolar fracture—One section of the alveolus is separated and the fragment, together with the teeth it carries, is driven in towards the palate or displaced in the opposite direction. Displacement is reduced by manipulation and fixation is secured by cap splints.

FIG 1474

Prominence of the posterior part of the ilium indicates sacro-iliac subluxation or dislocation. The displacement is easily felt and, as in this case on the left side it may be obvious on inspection.

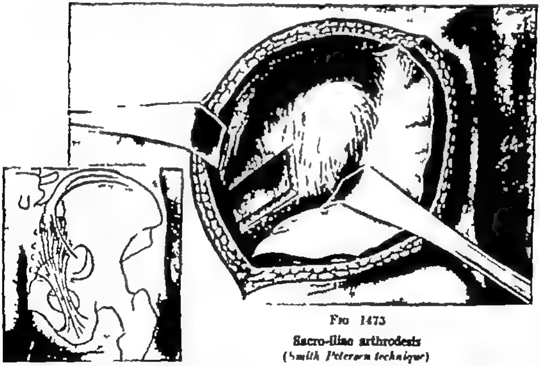

FIG 1473

Sacro-iliac arthrodesis

(Smith Petersen technique)

Through an incision centred on the posterior superior iliac spine and following the crest of the ilium, the dorsum ilii is exposed subperiosteally. A rectangular block of bone is cut out of the ilium exactly over the sacro-iliac joint. The block is lifted out and the articular cartilage on it deep surface removed. Cartilage from the articular surface of the sacrum is then excised by curette and gouge and finally the block of bone is replaced and punched deeply into the cavity so that it locks into the sacrum

CHAPTER XXXI

INJURIES OF THE CHEST

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Treatment—During the first week or two aggravation of the pain from respiratory movement may be relieved by strapping. Long strips of

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Kleiner, S. B. "Fracture of Rib by Muscle Action" (review of fifty-six reported cases). *Boston med. surg. J.*, 1924 190 1024.

Isolated fractures of the ilium and minor separations of the symphysis pubis also recover fully without special treatment The *surgeon must*, however satisfy himself that separation of the symphysis pubis is in fact an isolated injury If there is wide displacement of the pubic bones there is very probably an associated injury in the sacro iliac region which may easily be overlooked and often accounts for persistent disability

Sacro-iliac subluxation is the only isolated pelvic ring injury that is seriously significant Even without gross displacement, subluxation may cause persistent pain and incapacity The injury is to be recognised clinically by the local pain tenderness over the joint and typical displacement The ilium is pushed slightly backwards and towards the mid line The posterior

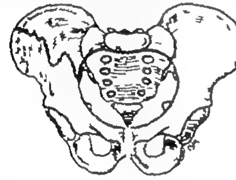

Fig 1476

Fig 1477

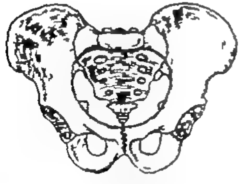

Fig. 1478

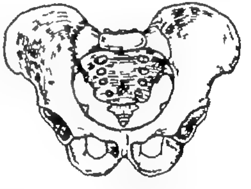

Fig 1479

Isolated injuries of the pelvic ring There is no marked displacement and no special treatment is indicated.

superior iliac spine is therefore more superficial than the corresponding bony prominence of the *opposite* side and *it lies nearer* to the spinous processes Radiographs also show that this part of the ilium is unduly close to the mid line and that it overlaps the shadow of the sacrum to an abnormal degree

The displacement is reduced in the same way that complete disruptions of the pelvis are reduced by rotating the ilium forwards The patient is laid on the normal side and pressure is applied over the front of the crest of the ilium The *joint is immobilised in plaster* for three months If there is persistent pain from imperfect reduction with instability of the joint and traumatic arthritis surgical fusion may be needed A wedge of bone out from the ilium is driven across the joint (Fig 1475) [1]

[1] Smith-Petersen, M. N "Sacro-Iliac Arthrodesis for Traumatic Arthritis." *J Bone Joint Surg*

strapping extending across the mid line both in front and behind are applied while the chest is held in the position of expiration The upper ribs may be supported by strapping from the region of the nipple over the clavicle to the lower angle of the scapula If the pain is still unrelieved the chest should be completely encircled so that respiratory movement is almost confined to the diaphragmatic and abdominal muscles

Procaine injection for fractures of the ribs—Success has been claimed for the treatment of fractured ribs by procaine injection Pain is relieved and strapping of the chest is unnecessary This freedom from symptoms may be attributable to the relief of muscle spasm or it is explained by the theory of Leriche (p 54) The point of maximal tenderness is localised and the overlying skin is anæsthetised A wider bored needle is then slid along the surface of the rib until the fracture is felt From 5 to 10 c c of 1 per cent novocaine is injected into the fracture hæmatoma and the surrounding muscles The same procedure is repeated at other fracture levels

Stove in chest—A severe crushing blow may fracture several adjacent ribs anteriorly and posteriorly so that a segment of the chest wall is completely separated Paradoxical respiration then occurs As the chest expands in inspiration the floating part retracts with expiration it expands If a large part of the chest wall is involved air cannot enter the lung or be expelled. Light sandbags or a tight dressing should be applied An artificial respirator is sometimes needed

SLIPPING RIB

Recurring luxation of a costo-chondral joint causes pain which is often attributed to neuritis pleurisy angina coronary thrombosis cholecystitis or kidney disease and sometimes to neurasthenia or malingering [1 4] There is often a history of injury followed by persistent pain which is severe and frequently radiating The pain is aggravated by abducting the arm playing games or lifting weights There is local swelling and tenderness over the costo-chondral junction The rib or cartilage may be unduly prominent and appear to be subluxated and recurrent subluxation may be proved by the clicking sensation which accompanies deep respiration movement of the trunk, or movement of the arm The symptoms are sometimes relieved by novocaine injection or by strapping the chest [5] Manipulative treatment has been credited with dramatic results though this is difficult to believe [6] If symptoms persist it is wise to cut down on the joint and excise the costal cartilage or the end of the rib

FRACTURES OF THE STERNUM

The sternum is often fractured when there is a severe fracture-dislocation of the thoracic spine but apart from this fracture of the sternum as an isolated injury is very unusual It may occur in motor accidents from the

Davies-Colley R., Mabon R B Marshall, C J Poynton, F J Russell, T N and Sultan, H K V "Slipping Rib" *Brit. med J* 1922, 1 432, 516, 602 and 664.
Cyriax E F *Practitioner*, 1919 102, 314
Blazard, D Slipping Rib *J Amer med Ass* 1931 97 23.
Graham, E Singer J J & Ballon H C Surgical Diseases of the Chest. Philadelphia Lea & Febiger 1935.
Ballon, H C and Spector L Slipping Rib. *Canad med Ass J* 1938 N.S 39, 355.
Hall, W A Displaced Ribs. *Lancet* 1933 1 1102.

COMBINED INJURIES OF THE PELVIC RING

The pelvic ring is made up of the anterior pubic segments which are developed for the protection of the pelvic viscera and for the attachment of muscles and the postero-lateral iliac segments which also serve the function of weight-bearing Combined fractures of the pelvic ring are of two types In the first both fractures lie in the pubic segments ; in the second one fracture is in the pubic segment and one in the weight bearing iliac segment

Combined injuries of pubic segment of pelvic ring—Double fractures of the pubic part of the pelvis are the result of lateral crushing ; The victim may be standing sideways to a wall and is crushed by a motor vehicle which strikes the opposite side of the pelvis The injury may be a bilateral fracture of both pubic rami or a unilateral fracture of both rami with separation of the symphysis pubis (Figs 1480 1481) The detached fragment of bone

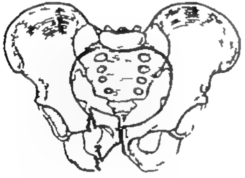

Fig 1480

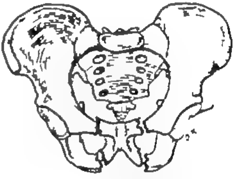

Fig 1481

Combined injuries of the pubic segment of the pelvic ring produced by lateral compression of the pelvis. There is only slight displacement Patient should be nursed on their backs.
(By courtesy of Brit. J Surg from the author's article 1914, 25, 773.)

is relatively small Its displacement is limited by the attachments of many muscles and whatever the degree of displacement there is no shortening of either limb and no alteration in the alignment of weight bearing joints As a rule therefore it may be ignored ; The patient is treated in recumbency for five or six weeks the lateral compression of the pelvis should not be increased by allowing the patient to lie on one side

Combined injuries of iliac and pubic segments of pelvic ring—The commonest combined injury causing complete disruption of the pelvis is a dislocation of the symphysis with a dislocation of the sacro-iliac joint Less frequently there is a dislocation of the symphysis with a fracture of the ilium near the sacro-iliac joint or a fracture of both pubic rami with a dislocation of the sacro iliac joint (Figs 1482 1484) One half of the pelvic girdle is widely displaced carrying with it the lower limb so that there is deformity and shortening

Unlike the first type of combined injury which is produced by lateral compression of the pelvis these injuries are produced by antero-posterior compression The patient is standing with his back to the wall when he

is crushed by a motor vehicle, or he is lying on the roadway and the wheel of the vehicle mounts one side of the pelvis. In other cases head-on collisions are responsible. The mechanism of injury is important because it gives the clue to the technique of manipulative reduction.

Mechanism of displacement in dislocation of the pelvis—Radiographic examination shows obvious separation of the two pubic bones but often with only slight displacement of the sacro-iliac joint which may be overlooked. Only careful examination shows that the ilium overlaps the back of the sacrum more than on the normal side and that the iliac joint surface is slightly higher than the sacral joint surface. Similarly, on clinical

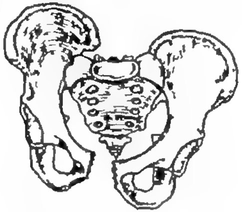

Fig. 1482

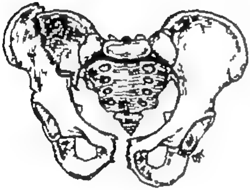

Fig. 1483

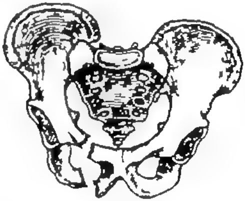

Fig. 1484

Combined injuries of the pubic and iliac segments of the pelvic ring produced by antero-posterior compression. There may be severe displacement. Patients should be nursed on their sides. *(By courtesy of "Brit. J. Surg." from the author's article.)*

examination it may almost be possible to put a fist between the displaced pubic bones and yet there is only a trace of undue prominence of the posterior superior iliac spine. This is because the displaced innominate bone is rotated round a longitudinal axis near the sacro-iliac joint. The dislocated half of the pelvis is swung outwards and only secondarily in more severe injuries is it displaced upwards into the loin. This outward rotation is shown in radiographs by the outwardly rotated position of the femur, the unusual prominence of the ischial spine and the disappearance of the obturator foramen (Fig. 1488). It is a displacement maintained by the weight of the limb.

FRACTURES OF THE VERTEBRAL BODIES OF THE LUMBO-DORSAL SPINE

Fractures of vertebral bodies are usually sustained from flexion compression injury at the upper lumbar or low dorsal levels By far the greatest number of all spinal fractures involve the twelfth dorsal and first two lumbar vertebræ Fractures in this region are nearly always sustained from flexion injury Extension injuries are unusual but, as we shall see later extension or hyperextension fractures are relatively more common in the cervical spine

Classification of lumbo-dorsal fractures of the vertebral bodies in accordance with the type and direction of violence—These injuries may be divided into three groups as determined by the direction of the force causing the fracture wedge compression fractures comminuted fractures and fracture-dislocations

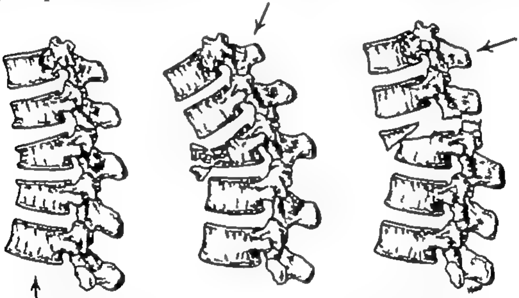

Fig 1495 Fig 1496 Fig 1497

The three types of fractures of vertebral bodies in the lumbo-dorsal spine are Simple wedge fracture from vertical compression (Fig 1495) comminuted fracture from acute angulation in flexion (Fig 1496) fracture-dislocation with forward displacement and injury to the apophysial joints (Fig 1497) It should be recognised that in all these fractures there may be lateral displacement as well as flexion displacement and particularly in fracture-dislocations, there may be rotational displacement

1) *Wedge compression fractures*—If a patient falls from a height in the standing or sitting position landing on his feet or buttocks so that there is vertical compression of the spine in its usual postural position of slight flexion one vertebral body or more usually several bodies may be compressed and slightly wedged anteriorly The anterior vertical depth is reduced by one quarter one third or even one half as compared with the undisturbed posterior vertical depth. Sometimes there may also be lateral wedging if at the moment of impact the trunk deviates to one side so that there is lateral as well as anterior compression. The intervertebral discs are usually undamaged and there is seldom rupture of the interspinous ligaments or of the ligaments of the apophysial joints

2) *Comminuted fractures*—If a heavy weight falls across the shoulders of a stooping patient so that the spine is suddenly forced forwards into an acutely flexed position there may be comminution of one vertebral body T

Many types of treatment have been devised to correct the displacement. Traction has been applied to one or both limbs, skeletal traction has been used, well leg traction has been employed,[1] pelvic slings and girdles have been devised,[2,3,4] operative wiring has been performed.[5] A most formidable operation has been suggested by which both obturator foramina are exposed and the two halves of the pelvis are forced together by tightening a "grab hook" fixed on to the bones. In all these procedures the patient has been treated lying on his back.

The key to successful reduction is the position of lateral recumbency. The dislocated pelvis is like a partly opened bivalve shell—an oyster or a mussel: when laid on the hinge at the back, gravity keeps the two halves apart, but when laid on one side the two halves close. Similarly, with the dislocated pelvis, if the patient lies on one side the two halves of the pelvis fall together.

TREATMENT OF DISRUPTIONS OF THE PELVIS

Watson-Jones method of postural reduction.[6]—Slight separations of the symphysis pubis with subluxation of the sacro-iliac joint may be reduced without anæsthesia. If there is greater displacement a general anæsthetic should be given. A plaster table or any form of pelvic rest is used with the perineal post removed. The patient is placed on his uninjured side with the ilium and trochanter lying on the pelvic rest and the two lower limbs held one above the other by an assistant. In many cases the dislocation is already reduced by the time the patient is in this position. If the pubic bones are not perfectly approximated and the posterior superior spine of the ilium is still unduly prominent, pressure should be applied over the crest of the dislocated ilium, pushing and rotating it downwards and forwards towards the normal half of the pelvis (Figs. 1485-1487). Accuracy of reduction may be confirmed by taking radiographs before the plaster is applied. If necessary the patient can be laid on the injured side so that lateral compression is increased by the addition of body weight.

The iliac crests are protected with adhesive felt, and a double plaster spica is applied. The spica should be moulded closely to the pelvis and lumbar region. The pelvic rest is then cut out, padding is inserted and the gap in the plaster is repaired. A post-reduction radiograph is taken through the plaster (Figs. 1489-1490). Throughout the period of recumbency the patient is encouraged to lie on one side. After four or five weeks the plaster may become loose and a new spica is then applied, again in lateral recumbency. Immobilisation is continued for three months. Throughout this time regular exercises are practised to prevent stiffening of the knee joints and to maintain the tone of the quadriceps muscles.

Treatment of fracture-dislocations of the pelvis.—The same routine may be adopted when instead of a dislocation of both joints there is a dislocation of one and a fracture near the other. In these cases the fragments do not always lock in the reduced position with the security and accuracy that are

[1] [illegible] B. "Sacro-iliac Dislocation Reduced by Hoke Traction." *Proc. R. Soc. Med.* (Section of Orthopædics), 1933, 27, 5 6.
[2] Böhler, L. *The Treatment of Fractures.* Bristol: John Wright & Sons Ltd., 4th ed., 1935, 15[illegible].
[3] [illegible], F. M. "Fractures of the Pelvis." *Amer. J. Surg.* 193[illegible], 30, [illegible].
[4] Bärd. "Luxations of the Os Innominatum." *J. Chir., Paris*, 1937, 49, 536.
[5] [illegible], G. "Traumatic Rupture of Symphysis." *Brit. Clin. Chir.* 1937, 165, 607.
[6] Watson-Jones, R. "Dislocations and Fracture-dislocations of the Pelvis." *Brit. J. Surg.* 193[illegible], 25, [illegible].

TYPES OF FRACTURE OF THE VERTEBRAL BODIES OF THE *LUMBO-DORSAL SPINE*

FIG 1498

Simple wedge compression fracture of a vertebral body

FIG 1499

Comminuted fracture of a vertebral body from acute angulation.

FIG 1500

Fracture-dislocation of the spine [illegible] displacement

FIG 1501

Fracture-dislocation of the spine with lateral displacement

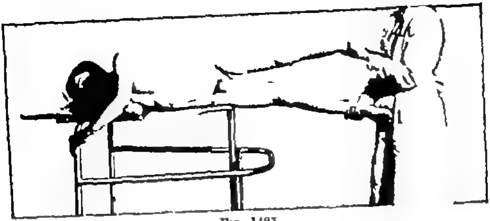

Fig 1485

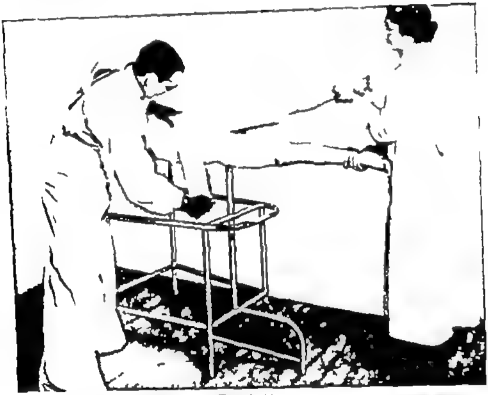

Fig 1486

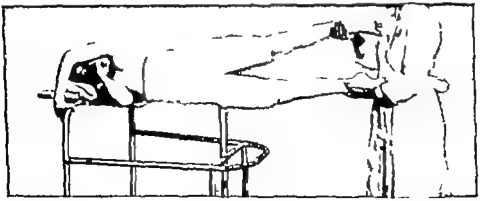

Fig 1487

Reduction and immobilisation of dislocations and fracture-dislocations of the pelvis by lateral recumbency The patient lies on the uninjured side The dislocated ilium is rotated forwards and downwards and a double plaster spica is applied (*By courtesy of "Brit. J Surg" from the author's article* 1938, 25, 73.)

interspinous ligaments are often ruptured or avulsed, and the angulation is so acute that the anterior inferior angle of the vertebral body above is driven into the upper surface of the fractured vertebra causing a wedge shaped depression (Fig 1499) The intervertebral disc between the two vertebræ is ruptured and destroyed There may also be driving of the anterior superior angle of the vertebral body below into the inferior surface of the fractured vertebra again with wedge-shaped compression and again with damage to this disc and rupture of the interspinous ligament Such comminution of one vertebral body usually represents a true flexion injury but there is sometimes lateral angulation, typically for example when a crouching miner lying half sideways in a low seam is crushed by a fall of roof

3) *Fracture-dislocation*—If a patient is struck behind the upper part of the trunk by the impact of a motor vehicle which not only flexes the spine but also drives the upper part forwards there may be fracture-dislocation with injury to the vertebral body rupture of the interspinous ligament and dislocation of the apophysial joints or fracture of the laminæ or pedicles (Fig 1500) Just as with the other two groups of spinal fracture there may be not only forward displacement but also lateral displacement, and in these injuries special care should be taken to recognise the rotational element of the violence The upper segment of the spine is often rotated either to the right or to the left so that there may be a fracture or ligament injury of one apophysial joint associated with complete dislocation of the corresponding joint on the other side sometimes with over riding and interlocking of the articular facets (Fig 1501)

Classification of fractures of the lumbo-dorsal vertebræ into stable and unstable (safe and unsafe) fractures—In earlier pages it has been pointed out that the stability or instability of nearly all joint injuries and fracture-dislocations is related closely to associated injuries of the neighbouring ligaments and that the degree of safety or the tendency to redisplacement often depends upon this (Figs 1280-1287) This has particular significance in fractures of the spine If the interspinous ligament is not ruptured and there is no severe injury to the ligaments of the apophysial joints or to the intervertebral disc and its annular ligament fractures of the vertebral bodies are usually quite stable in the position of slight deformity produced at the moment of injury and they are safe from increasing displacement This is true even if the injured spine is not immobilised in plaster If it can be certain that there is in fact such stability it may often be decided that the degree of wedge-compression produced by the injury is not in itself likely to cause serious disability Since there is an assurance that the deformity will not increase the injured spine may be treated by early active exercise without immobilisation On the other hand if the interspinous ligament has been completely ruptured or avulsed and there is tearing of the ligaments of the apophysial joints the vertebral fracture is not stable and it is not safe, there may well be recurrent and increasing displacement with a threat of late compression of the cauda equina or spinal cord These fractures and fracture-dislocations of the spine must be protected at least in a plaster jacket and often by the internal fixation of plates with bolts or screws

Clinical and radiographic diagnosis of vertebral fractures—If a patient has fallen from a height or sustained a flexion injury of the trunk, and

FIG. 1488

Dislocation of the left side of the pelvis. The rotation of the ilium is shown in the displacement of the left symphysis away from the mid line, the prominence of the ischial spine, the disappearance of the obturator foramen and the abnormal overlap of iliac and sacral shadows. The arrow points to the lower margin of the sacral articular surface

FIG. 1489

Same case as that of Figure 1488 twelve months after reduction by simple lateral recumbency with the application of a double plaster spica. The separation of the symphysis is corrected and the sacro-iliac displacement is reduced

complains of pain in the back it is very probable that he has sustained a vertebral fracture This cannot be excluded until a full radiographic examination has been made It may often be possible to recognise the level of injury by the slight prominence of one spinous process, and by local pain and tenderness on deep pressure or percussion Nevertheless the whole of the lumbar and dorsal regions should be examined by x rays because there is often injury at more than one level Radiographs in lateral projection show wedging of one or more vertebral bodies with some buckling of the upper and lower anterior margins

FIG 1002

Scheuermann's disease in a patient aged eighteen showing narrow discs, wedged bodies and hernial protrusions of nucleus pulposus

FIG 1003

Old Scheuermann's disease in a patient aged thirty five showing narrow discs, wedged bodies and lipping of the vertebral body margins.

It is important in these radiographic studies to distinguish stable wedge-compression fractures of a simple type from unstable fractures with damage to the apophysial joints and interspinous ligaments in which recurrent or increasing displacement may arise Films of the best quality are needed often taken with a cone to prevent scatter of rays and increase the clarity of the films Even when there is no obvious fracture of the neural arch or articular processes and no displacement of the apophysial joints a wedge compression fracture may be of the unstable type because there has been complete rupture of the interspinous ligament This may be recognised by widening of the space between the spinous processes as seen in the lateral projection If any doubt remains additional lateral films should be taken with the spine gently flexed and also fully extended

observed in combined dislocations The fragments are more mobile so that there may sometimes be over riding of the pubic bones

Continuous traction after reduction by lateral recumbency—In addition to rotatory displacement there is sometimes upward displacement of the innominate bone into the loin While the patient lies in lateral recumbency this is reduced by thrusting downwards on the crest of the ilium A plaster spica is then applied and continuous traction may also be used The limb on the dislocated side is supported in a Thomas s splint incorporated in the plaster after cutting off the ring Skin traction or skeletal traction from the head of the tibia may be used the foot of the bed being raised on blocks

Treatment of dislocations of the pelvis with rupture of the bladder—If disruption of the pelvis is complicated by extra peritoneal or intra peritoneal rupture of the bladder, the co-operation of a urological surgeon should be sought Immediate operation is necessary the bladder and prevesical space being drained Leakage of urine is controlled by a tied in suprapubic catheter and suction apparatus For the first few days a sling supported by weights over an overhead beam may be used to prevent lateral spreading of the pelvis but after that time the dislocation should be reduced by lateral recumbency a short double plaster spica being applied The injury to the bladder the prevesical tissues and the pubis is one plane of rupture through the tissues of the mid line and the two halves of the bladder wall remain attached to the corresponding halves of the pelvis Infection in the prevesical tissues may increase the fixation of the bladder wall to the bone If the pubic bones remain in their dislocated position all the soft tissues of the front of the pelvic cavity are held apart (Fig 1490) Moreover, every time the patient is turned the pelvic bones are pushed together and then forced apart and sutures in the wall of the bladder may tear through It is clear therefore that reduction of the pelvic dislocation assists in approximating the rupture of soft tissues and that immobilisation of the pelvis promotes repair of the visceral injury Leakage from the cystotomy wound may be controlled during application of the plaster by a Malecot or de Pezzar catheter A generous window is cut in the mid line to expose the abdominal wound and allow proper supervision and nursing with suitable drainage of the bladder

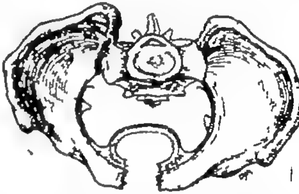

Fig 1490

Dislocation of the pelvis with rupture of the bladder The two halves of the bladder are held apart by the two halves of the pelvis and there is no satisfactory approximation until the dislocation is reduced

Treatment of dislocations of pelvis with rupture of the urethra—Reduction and immobilisation of the pelvic bone injury may also assist the urological surgeon with his treatment of an injury to the urethra In some cases it has proved quite impossible to pass a catheter through the urethra into the bladder while the pelvis was dislocated, whereas as soon as the dislocation was reduced by laying the patient on one side a catheter was passed without

In the low dorsal spine there may sometimes be confusion between wedge compression fractures of the vertebral bodies and Scheuermann's osteochondritis—a growth disturbance occurring in late adolescence which if left unprotected also causes wedging of vertebral bodies. As a rule this disease involves the seventh to the eleventh dorsal vertebræ and its true nature is disclosed in lateral radiographs by irregularity in the contour of opposing surfaces of the vertebral bodies, herniation of the nucleus pulposus causing depressions in the intervertebral surfaces with protective condensation of the adjacent bone, and narrowing of the disc spaces (Figs. 1502, 1503). Less commonly a similar growth disturbance occurs in one or two of the lumbar vertebræ.

Wedge-compression fractures of the lumbo-dorsal vertebræ—*Examples of injuries causing wedge-compression fractures*—Simple wedging of one or several bodies from vertical compression of the spine in its very slightly flexed position is the commonest type of spinal fracture, accounting for about 60 per cent of spinal injuries. As a rule two, three or even more vertebræ are wedged. Perhaps the record is held by a pilot who made a heavy forced landing and fractured ten vertebræ in the lumbar and dorsal regions. As a rule the patient has fallen from a height, from a ladder or scaffolding, and landed on his feet so that compression fractures of the calcaneum and lower end of the tibia are associated with compression fractures of the spine. One workman fell from the top of a building and landed in soft soil into which his feet and legs were buried so that he was still standing at the end of it all—with wedge fractures of several vertebræ. A sailor fell from the crow's nest down the inside of a ship's mast; in so confined a space he was bound to land upright on his feet, thus fracturing both heels and the spine. A sailor may jump from the uppermost side of the tilted deck of a sinking ship and fail to leap wide enough, so that instead of landing in the sea he lands on the side of the ship or the bilge-keel now appearing above sea level. The injury to the spine is of course just the same if the patient lands in a sitting position, thus accounting for spinal fractures in many industrial injuries, in the passengers and crew of aircraft which make belly landings, and in parachutists who seldom land on their feet but nearly always on the buttocks or low back. It also explains the spinal fractures often sustained in domestic life when a patient just sits down heavily from an awkward stumble. It does *not* follow that a fall from a great height will cause more serious fracture than a simple injury such as this. One day in the last great war an airman on "spotting duty" stepped off the roof of a hangar in the blackout and fell one hundred feet; he picked himself up and walked to the first-aid post with a minor spinal fracture, whereas on the same day another airman slipped in the mud, sat down heavily, and was taken away on a stretcher with much more severe spinal fractures as well as fractures of the carpal scaphoid bones of both wrists.

Compression fractures of vertebral bodies in elderly patients—This mechanism of spinal compression fracture from sitting heavily occurs with still greater frequency in elderly patients whose vertebræ already show evidence of senile osteoporosis with softening of bone and cupping of the vertebral bodies from pressure of the intervertebral discs. These softened vertebral bodies may also be crushed from simple flexion strains such as lifting a weight in the

FIG. 1401

Dislocation of the right side of the pelvis with rupture of the bladder. The arrows point to the lower margin of the sacral joint surface on each side.

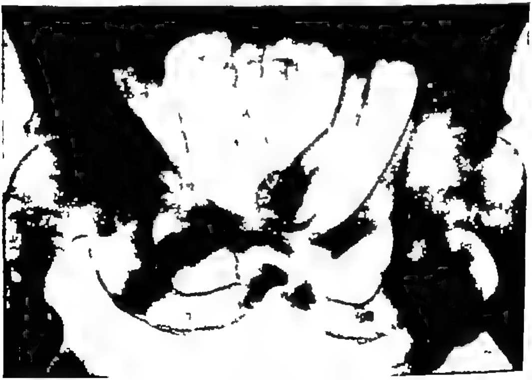

FIG. 1402

Same case as that of Figure 1401. Radiograph through plaster taken in operating theatre with portable unit. A de Pezzar catheter is preventing leakage from the bladder. Although it is three weeks since injury the dislocation is reduced. Plaster was retained for three months and despite continued bladder drainage, prevesical infection and osteomyelitis of the pubis, there was no serious nursing difficulty.

stooped position. In fact when the patient's spine is x-rayed there is often evidence of many former compression fractures at different levels which clearly had been sustained at different times and had passed unrecognised. With the frequent pain in the back associated with senile osteoporosis and secondary intervertebral arthritis occasional attacks of more severe pain had been accepted without thought of the possibility of fracture. Any other general skeletal disorder causing osteoporosis, malacia or destruction of bone in the vertebral column obviously predisposes to vertical compression fracture. These were discussed in the first volume in Chapter XVII.

Compression fractures of the dorsal spine—Wedge-compression fractures seldom occur in the mid-dorsal or upper dorsal spine in ordinary domestic or industrial life. The dorsal spine forms the arm of a lever which has its fulcrum at the dorso-lumbar junction. The strain of forcible flexion movement is therefore transmitted to the level of the last dorsal and first two or three lumbar vertebræ and fractures nearly always occur at this level. There is one group of high dorsal compression fractures which should be mentioned in passing because it is at least of historical interest. It was sustained by fighter pilots in the last great war just as frequently as lumbar fractures because of the special safety harness they had to wear. The ordinary safety belt worn by passengers in all aircraft is at the waist level so that if there is heavy landing with forward fling of the trunk causing injury to the spine the fracture will be at the dorso-lumbar junction. The pilots of faster flying machines wore a special harness holding the shoulders back, by which to prevent impact of the head against the instrument panel so that in the event of sudden forcible flexion of the trunk the site of angulation was raised to the upper dorsal level.

Fractures of the lumbo-dorsal vertebræ from lateral compression—This injury occurs with particular frequency in miners who are lying crouched half sideways in a low seam and are crushed by a fall of roof. The importance of the injury has been emphasised by Nicoll in whose series of 152 patients with spinal fracture there were no less than twenty-one with lateral compression. As a rule the injury falls into the category of stable or safe fractures but in two cases there was severe injury to the soft tissues with a large retroperitoneal hæmatoma which was mistaken for rupture of an abdominal viscus and laparotomy was performed.[1] Moreover injury to nerve roots from stretching occurs more frequently than in the usual fracture with anterior compression of the vertebral body.

Comminuted fractures of the lumbo-dorsal vertebræ—A comminuted fracture occurring from acute forward angulation of the spine is a very different injury from a simple vertical-compression fracture. Not only is the bone severely comminuted by impact of the anterior margins of the vertebral bodies above and below which produces wedge-shaped compression defects in the upper and often the lower surfaces of the injured body but there is also injury to the soft tissues. The very fact that the anterior margin of an adjacent body has ploughed into the middle of a fractured body shows that at the moment the violence was sustained there was such a degree of hyperflexion deformity of the spine that the interspinous ligaments must have been avulsed and the apophysial or interarticular joints must have been dislocated or the articular processes fractured (Fig 1,404 1,407).

[1] Nicoll, E. A. Injuries of the Back. Brit. med. J. 1 [illegible]

difficulty The replacement of the bones has thus replaced the soft tissues so that kinking and distortion of the urethra has been relieved

INJURIES OF THE SACRUM AND COCCYX

Fractures of the sacrum—Extensive crushing injuries of the pelvis are often accompanied by fractures of the sacrum Isolated fractures are rare and the injury is usually a crack fracture without displacement recovering rapidly and completely Occasionally the lower half of the sacrum is displaced forwards into the pelvic cavity, and there may be injury to the distal sacral nerves with saddle anaesthesia of the gluteal regions and incontinence It may sometimes be possible to replace the bone by manipulation with one finger in the rectum

Fractures of the coccyx—A fall in the sitting position may cause contusion fracture or dislocation of the coccyx If the distal fragment is completely separated it is pulled forwards by the ano-coccygeal and levator ani muscles The injury always causes considerable pain which may persist for several months There is difficulty in sitting and the only comfortable positions are standing or lying No special treatment is needed except to minimise pain by protecting the bone from further injury It is wise to give a warning from the beginning that recovery from this injury may not be complete until after many weeks or months because otherwise disappointed patients develop functional disorders There has been far too much emphasis on the functional or neurotic aspect of coccydinia It is not a functional disorder at all Patients suffering from this disability are not neurotic—it is only that their symptoms have not been understood

Operative treatment—The slowness of repair of fractures of the coccyx is explained by the pull of many muscles inserted into the bone If there is non union or mal union the symptoms are relieved when the coccyx is excised. If the operation is done with care and the stump of the sacrum is rounded the results are entirely satisfactory [1 2]

Coccydinia from retropulsion of the lumbo-sacral disc—It is now being recognised that even when there has been no actual fracture or displacement of the bones of the coccyx there may be persistent pain in the coccygeal area arising from prolapse of the lumbo-sacral disc in the mid line with resulting pressure on the sacral and coccygeal nerves Let us dismiss once and for all the suggestion that coccydinia is a simple manifestation of hysteria or an evidence of functional disorder

Lewin, P The Coccyx—its Derangements and Treatment. *Surg Gyn Obstet* 1927 45, 705.
Johnson, H. F Derangements of the Coccyx." *Neb St. med J.*, 1936 21 431.

FIG. 1504

FIG. 1505

Comminuted fracture of vertebral body (Fig 1504). Post reduction x ray shows complete replacement of marginal fragments and full opening of intervertebral disc spaces.

FIG 1506

FIG 1507

Comminuted fracture of a lumbar vertebral body—part of a fracture-dislocation of the spine with paraplegia from injury to the nerve roots. The displacement was reduced by simple extension of the spine There was complete recovery from the paralysis.

CHAPTER XXXIII

FRACTURES AND DISLOCATIONS OF THE SPINE

'He broke his back'—this observation has long implied a certainty of permanent crippling not only in the belief of most patients but unfortunately in the minds of many doctors. 'He broke his neck'—this still more sinister phrase has often suggested something near to death. It is of course true that some fractures of the vertebral column are associated with damage to the spinal cord or nerve roots which may even threaten life when the injury is at a high dorsal or cervical level, *but the fact is that nearly all vertebral fractures,* or at least 80 per cent of them, are just as simple as fractures of the wrist, fractures of the ankle, fractures of the knee, or any other fractures.

The first duty of a surgeon who treats patients with fracture of the spine is to give reassurance. If there is no injury to the cord and no threat of such injury, it should at once be explained how simple it is: there will of course be complete recovery and no danger is to be feared. The distinction between safe and unsafe fractures of the vertebral column will be discussed in later pages, but meanwhile let it be emphasised that, even without any

Fig. 1403

Fractures of the transverse processes arise from avulsion of the quadratus lumborum, and the injury is more severe than the radiograph suggests. There is extensive tearing of fasciæ, aponeuroses, muscles, blood vessels and nerves.

treatment at all, complete functional recovery is usually to be expected from fractures of the lumbar transverse processes and dorsal spinous processes *and from most fractures of the vertebral bodies.*

Three groups of spinal fracture, corresponding to the three anatomical parts of the vertebræ, should be distinguished: (1) fractures of the spinous and transverse processes, which serve for the attachment of muscles and may be avulsed by muscle traction; (2) fractures of the vertebral bodies

It is clear that the intervertebral disc above and sometimes below as well must have been disrupted. The force may be so great that fragments of the body are displaced backwards into the neural canal, thus increasing the risk of damage to the cauda equina or conus medullaris (Fig 1508) It is true that most of these displacements can be reduced if the spine is gently extended but the fracture is obviously of the unstable type An injury causing local disruption, comminution of bone, rupture of discs, fractures of pedicles, tearing of ligaments, dislocation of interarticular joints encroachment on foramina, pressure on nerve roots, and sometimes involvement of the cauda equina is likely to cause persistent aching pain even if the displacement is reduced and the reduction is maintained. Moreover these fractures are very slow in consolidating and, if conservative measures are relied upon immobilisation in plaster needs to be continued for at least six months, or even for as long as nine or twelve months. The problem may not be solved even then because aching pain from arthritis of the intervertebral and interarticular or apophysial joints persists until bony ankylosis develops Spontaneous ankylosis by bone bridges between the vertebral bodies and ossification round the lateral joints may be complete only after several years—and pain discomfort and weakness lasting for a very long time may so influence the patients that they can never be convinced of complete recovery The conclusion must be accepted that whereas functional recovery after a stable wedge-compression fracture can be achieved within a few months by early active exercise or at the most by simple reduction and immobilisation in plaster functional recovery after a severely comminuted fracture may be achieved only after several years by ankylosis of the vertebral bodies It is evident that such ankylosis will be the best end result The sooner it is secured the better and it should be achieved by surgical intervention fusing the spinous processes and laminae

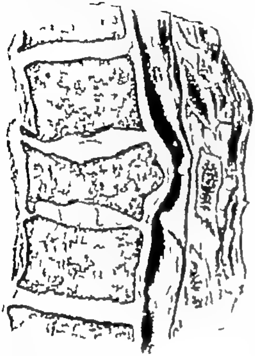

Fig 1508

Specimen of comminuted fracture of a lumbar vertebral body with driving of fragments back into the spinal canal with resulting paraplegia from which the patient died.

Fracture-dislocation of the vertebrae—In fracture-dislocations there is not only compression or comminution of one vertebral body but also forward or lateral displacement of the vertebral body above associated with displacement of one or both apophysial joints from dislocation of the joint or from fracture of the articular facets Flexion rotation injuries may cause overriding and locking of these articular facets One other type of rotational fracture-dislocation in which the vertebral body is not crushed but from which a slice is sheared off the upper margin must also be considered, especially in relation to vertebral fracture-dislocations with paraplegia

which transmit weight and may be crushed by vertical compression 3) fractures of the articular facets of the neural arch which protects the spinal cord with displacement usually arising from rotational injuries which also shear fragments from the vertebral bodies or from forcible flexion which comminutes the bodies

FRACTURES OF THE LUMBAR TRANSVERSE PROCESSES

The quadratus lumborum muscle arises from the crest of the ilium and is inserted into the lumbar transverse processes and the lower ribs Sudden contraction of this muscle against resistance may cause avulsion and

FIG. 1404
Fractures of the third, fourth and fifth lumbar transverse processes on the right side with subperiosteal ossification in the origin of the quadratus lumborum from the ilium

displacement of fragments of bone from the processes These fractures occur from the thrust of a weight such as a sack of flour which a workman is shouldering against the side of the upper trunk forcing it to the opposite side against the resistance of the strongly contracting lumbar muscles It is the same type of injury as that which gives rise to fracture of the patella fracture of the olecranon and other avulsions of muscles from their site of attachment to bone There may be an isolated fracture of only one lumbar

TREATMENT OF STABLE LUMBO-DORSAL FRACTURES BY EARLY EXERCISE

If from clinical and radiographic examination the surgeon can be satisfied that a simple wedge-compression fracture of a vertebral body is not associated with complete rupture of the interspinous ligaments, or with dislocation of the interarticular joints, or with over riding of the articular processes, so that it is known that deformity will not increase despite lack of external protection, it is wise to treat the fracture as if it were no more than a soft tissue injury This is the method of treatment that has been advocated so vigorously by Nicoll[1,2] The patient is put to rest in bed for two or three weeks perhaps with a pillow behind the back but with no attempt to immobilise the spine or to maintain complete reduction of the fracture After the first few days extension exercises are practised The patient turns on to his face and with increasing energy, practises extension exercises by which to maintain and increase the strength of the spinal muscles Remedial exercises are continued in a gymnasium, the emphasis of all these exercises during the first few weeks being on extension rather than on flexion movement Very often the recovery is sufficiently good after two or three months for the patient to be able to go back to work.

This plan of treatment is undoubtedly right in simple compression fractures of vertebræ sustained by elderly patients with spinal osteoporosis In them there is no need at all to immobilise the spine in plaster For the treatment of the injury itself all that is required is a short period of bed rest—but of course it must be added that in order to prevent repeated injuries of the same type, and to relieve the pain that arises from arthritis of the intervertebral joints in consequence of the spinal osteoporosis a light posterior spinal support should usually be fitted and be worn regularly

This treatment is also wise for most simple compression fractures of the dorsal spine In younger patients fractures at this level are very rare though they do occur with somewhat greater frequency in pilots sustaining crash landing with a harness which transmits the level of flexion injury to the mid-dorsal area Once again such fractures are usually best treated without attempted manipulative or postural reduction, and without immobilisation in plaster, but by simple bed rest for a few weeks and exercise of the spinal muscles

TREATMENT OF UNSTABLE LUMBO-DORSAL FRACTURES BY REDUCTION AND IMMOBILISATION IN PLASTER

Although in many circumstances it may be best to treat stable and safe compression fractures of the vertebral bodies by early exercise—especially in the dorsal region and in elderly patients with osteoporosis—there is still no doubt in my mind that the best routine treatment for such fractures in healthy young adults is to correct the displacement and immobilise the

Nicoll, E. A. "Redevelopment of Muscle Function. Surgeons' Conference of the Miners Welfare Commission, 1947 *J Bone Joint Surg.*, 1948, 30-B, 392.
Nicoll, E. A. "Injuries of the Back." *Brit. med. J.*, 1932, 1 879 and 928.
Causealbergue R. an. "Traitement des fractures de la colonne vertebrale." *Rev med de Liège* 1954 9, 457

Fractures of dorsal spine in convulsive therapy—In these fractures there is again no need for immobilisation in plaster. (Meacham, J Scruggs, J R., Calhoun, J D "Convulsive Fractures of Dorsal Spine following Electric Shock Therapy" *Radiology* 1950 54, 180.)

transverse process without displacement but sometimes two or three processes are torn away and separated If the violence is still greater a line of injury may be traced from a fracture of the ilium through fractures of all five lumbar transverse processes to fractures of the lower ribs (Figs 1493 1494) It is evident that the bone injury may not then be the most important part of the injury What matters more is that there is extensive tearing of muscles fasciae and aponeuroses with haemorrhage and serous exudation The severity of these injuries has often been underestimated because the radiographic evidence of bone damage has appeared to be slight So much has this been so that patients have often been charged with neurasthenia or malingering when they continued to complain of persistent pain after many weeks or months The fact is that the associated tearing and rupture of soft tissues is often very extensive The correct treatment is to protect the torn tissues during the first few weeks by firm bandage or strapping over a thin layer of non-adhesive felt or even to use a plaster jacket for a week or two, and only after that to begin active exercise by which to prevent the formation of adhesions Of course there must be no forcible passive stretching or repeated manipulation pursued vigorously with the intention of preventing stiffness because this defeats its own object

FRACTURES OF THE DORSAL SPINOUS PROCESSES

"Clay shovellers' fracture"—The spinous processes of the lumbo-dorsal and cervical vertebrae are seldom injured by direct violence Very occasionally a hammer or some other tool is dropped by a workman high on scaffolding on the back of another man working below who is stooping so that his dorsal spinous processes are relatively prominent and the blow fractures a spinous process More often this injury is caused by avulsion of the muscles attached to the seventh cervical or first dorsal spinous processes [1 2] It has become known as the shovellers' fracture because it is so often sustained by men working on heavy soil or clay who at the moment of driving in a shovel or spade or of thrusting the laden shovel upwards experience a sharp and snapping pain high between the shoulder blades Radiographs show that the spine of the seventh cervical or first dorsal vertebra has been avulsed I was never able to understand why this injury which occurs so seldom in most countries that few surgeons have ever seen more than two or three examples was so common in Europe and especially Germany in the early nineteen thirties Within two or three years Zollinger reported seventy-eight cases [3] Debuch 187 cases [4] and Matthes 107 cases [5] Perhaps it is that in contrast with others these labourers worked harder and for longer hours in conditions leading to greater fatigue Of course the fracture is not serious There is need only to rest the patient for a few weeks ordinary active exercise being continued throughout Only in exceptional cases where pain persists because there is muscle pull on a weak fibrous junction, need excision of the avulsed fragment be considered

Ghormley R. K. and Hoffman, H O F Fractures of Vertebral Processes. Proc Mayo Clin. 1942, 17, 17
M K Hall (report of fifteen cases, eleven in men shovelling clay one shovelling gravel, one shovelling lime and one pitching hay) J Bone Jt Surg 1940 22, 63
Zollinger F Isolated Spinous Process Fractures—Schipper' Disease (seventy-eight cases)." Schweiz med. Wschr 1937 18, 4— 615
Debuch, L. Arch orthop Unfallch 103 37 423
Matthes H G Arch. orthop Unfallch 103 37 232.

spine in plaster About twenty five years ago I described a simple method by which such reduction could be achieved by placing the patient prone between two tables—a postural reduction that needed no anæsthetic and no manipulation.[1,2] Despite all critical comments this has stood the test of time In a consecutive series of more than one thousand vertebral fractures sustained in pilots and ground staff during the last great war treated by the team of orthopædic surgeons who worked with me no less than 94 per cent went back to duty[4] By extending the spine to the normal limit displacement of simple compression fractures of the vertebral bodies can be corrected and if the spine is immobilised in hyperextension in plaster for three or four months the correction can be maintained It is quite untrue to suggest that such immobilisation gives rise to permanent stiffness or any other permanent disability (Fig 1522) It is the best method of treatment of compression fractures in which there is no disruption of the apophyseal joints or interlocking of the articular facets

The patient is laid face down with his lower limbs resting on one table supporting himself by the arms on another table at a higher level so that the spine gently sags to the normal level of hyperextension (Fig 1509)

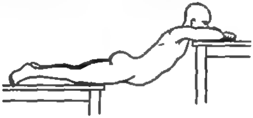

FIG 1509

Watson-Jones technique for postural reduction of vertebral body fractures.

The essential principle is that of postural reduction There is no manipulation no force and no violence Simply by placing the patient in the right position the displaced fragments of the fractured vertebra find their correct place There is of course no need for an anæsthetic It is true that the position is uncomfortable There is discomfort in the arms where the weight of the trunk is borne as well as in the stretched abdominal muscles but there is seldom severe pain The ordeal is not too great A plaster jacket is applied from the pelvis to the upper chest extending from the symphysis pubis below to the clavicles above It must of course be understood that the two-table method of postural reduction succeeds only if the tables are so placed that the spine does actually extend to its normal limit (Fig 1510) If the lower table gives support not only to the lower limbs but also to the pelvis there will be incomplete extension of the lumbar spine and similarly if the patient lies too far forwards over the upper table there will be incomplete extension of the dorsal spine (Fig 1511) The tables must be placed at such a distance from each other that as the patient lies stretched between them the spine is fully extended

Watson-Jones, R Brit Orth Assoc Annual Meeting, 1930 Report. *J Bone Joint Surg* 1931 13, 343
Watson-Jones, R *Brit med J* 1931 p 300.
Watson-Jones, R. *J Bone Joint Surg* 1934 16, 30
Watson-Jones, R. Presented in summary to the International Society of Orthopædic Surgery and Traumatology One Thousand Fractures of the Spine 1949

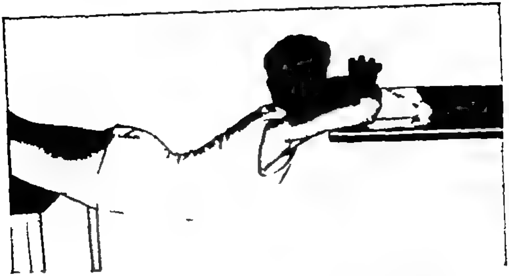

Fig 1510

Correct position for postural reduction of a fracture of the spine The lower table extends to the upper thighs; the upper table is clear of the chest.

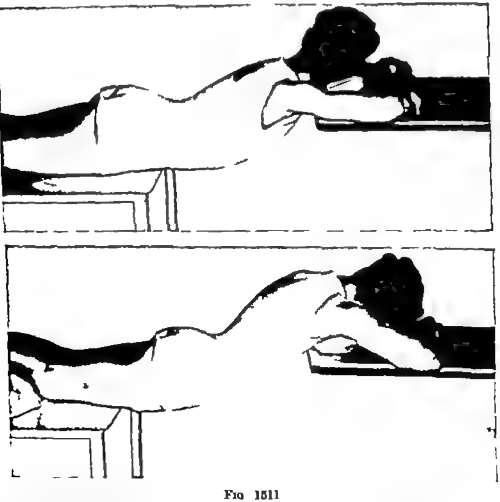

Fig 1511

Incorrect positions for postural reduction. If the lower table extends beyond the groins, the pelvis does not tilt forwards and the lumbar spine is not fully extended. If the upper table is too near the chest the plaster cannot be carried high enough and the dorsal spine is not fully extended.

the interspinous ligament and dislocation of the apophysial joints, there may be rotational displacement with over riding and interlocking of the facets The articular processes become locked in such a way that simple extension movement does not replace them but separates the vertebral bodies and causes traction injury of the spinal cord and the cauda equina (Figs 1524-1527) the vertebræ do not slide backwards into position, they hinge with pivoting on the articular processes Paraplegia may be produced even when at first there was no nerve injury Such fracture-dislocations must be reduced by open operation, no attempt being made to extend or hyperextend the spine until the locked articular processes have been exposed and replaced either by excision of one of the facets or by the leverage of a suitable instrument A plaster jacket is applied for about four months

FIG 1528

Comminuted fracture due to hyper extension The anterior marginal fragments are avulsed by the anterior common ligament.

FIG 1529

Hyperextension fracture of both pedicles of the first lumbar vertebra sustained spontaneously by an acrobatic dancer while on the stage

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D

Fractures of the lumbar spine caused by hyperextension—Although nearly all vertebral fractures are caused by flexion injury some are caused by hyperextension One type in which the anterior half of the body is separated into two quadrants the upper tilted and displaced upwards, and the lower tilted downwards is shown in Figure 1528 Another type of hyperextension fracture which is still more unusual, is shown in Figure 1529 This was in an acrobatic dancer who on one occasion went on to the stage without the usual fifteen or twenty minutes of loosening and limbering In the course of her dance when with her spine fully hyperextended and her head between her legs there was an ominous crack she suffered agonising pain having sustained a fracture of the neural arch of the first lumbar vertebra These injuries should be treated by immobilisation in a plaster jacket applied with head traction—neither in overextension nor in flexion (Fig 1523)

Other methods of achieving extension of the spine have been devised [1-4] The *prone patient may be supported on a sling or hammock*, or on the canvas of a Rogers frame or the supine patient is laid on curved strips of metal or on the kidney bars of an operation table (Figs 1512 1513) The important principle of the two-table method is that the trunk sags to its own normal limit of extension not being forced beyond it by appliances The technique of Davis [4] achieved similar extension by slinging the feet from an overhead pulley but this is not now generally used (Fig 1514)

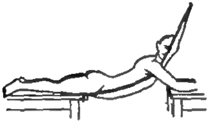


Fig 1512

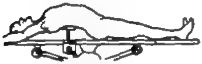


Fig 1513

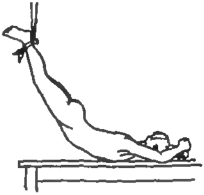


Fig 1514

Other methods of reducing fractures of the spine by hyperextension

Figure 1514 shows the technique of Davis, the feet being slung from an overhead beam The method of the hammock shown in Figure 1512, and of the kidney rest shown in Figure 1513, do not conform to the principle of postural reduction in which the spine finds its own limit of extension.

As soon as the plaster is dry certainly within a day or two, exercises for the spinal and abdominal muscles should begin They should be practised at regular intervals hourly throughout the day While lying prone with the arms by the side the patient slightly raises his head and shoulders from *the bed and lowers them again so that the extensor muscles of* the spine are firmly contracted Similarly the lower limbs are extended at the hip joints (Figs 1517 1518) Within a few days the patient may be allowed to get up and about and to dress normally suitable clothes being fitted over the plaster jacket He should engage in ordinary activities As time goes on still more vigorous remedial exercises should be supervised in the gymnasium with the aid of medicine balls wall bars pulleys and weight Recreation should be encouraged in the playing fields (Figs 1519 1521) The plaster cast should be kept in position for not less than three months If the patient has done his exercises regularly it will be found at the end of that time that there is a surprisingly good range of spinal movement within an hour or two of removing the plaster—and a normal range of movement of the spine will be regained within a week or two (Fig 1522) This must at first seem surprising but it is really not so it is only conforming with the principle that we have recognised in all other injured joints immobilised in plaster

Rogers, W A "An extension Frame for the Reduction of Vertebral Fractures." *Surg Gyn. Obstet.*, 1930, 50, 101
Rogers, W A. "Treatment of Fractures of Vertebral Bodies." *Arch. Surg* 1935, 30, 284.
Ryerson, E. W "Automobile Jack for Fractured Spine" *J. Amer med Ass* 1934 103, 862.
Davis, A G *J Bone Joint Surg* 1929 11 133 and 1938, 20, 429
Tucker J T "Treatment of Fractured Spines." *Virginia med Mon.*, 1934 61 154
Johnson, H. F "Compression Fracture of the Spine." *Nebraska State med. J.*, 1927 2, 1.

FRACTURES AND DISLOCATIONS OF THE CERVICAL SPINE

Four groups of injury to the cervical vertebræ may be differentiated 1) sprains and subluxations (or momentary dislocations) of the joints, 2) crush fractures of the vertebral bodies from flexion injury 3) dislocations of the intervertebral joints from flexion injury 4) injuries of the intervertebral joints from extension injury We must consider separately the special problems of fractures and dislocations of the atlas

Sprain or strain of the cervical joints—A sudden twisting or jerking movement of the neck may strain the interarticular ligaments without actually displacing or dislocating the joints There is local pain, movements are guarded by muscle spasm, and œdema and hæmorrhage round the adjacent nerve roots may cause pain referred to the arm forearm and hand especially when there is already degenerative change or spondylosis such as occurs so frequently in middle-aged and elderly patients Such a sprain or strain of the joints must be carefully differentiated from subluxation or momentary dislocation If there is no displacement the lateral radiograph shows that the joint surfaces of each pair of articular processes are strictly parallel—*but lateral views must also be taken with the spine gently flexed* An incomplete dislocation may be reduced spontaneously by extension of the neck, and radiographs in this position are often misleading (see page 157 Figures 273-274)

FIG 1530

Cervical interarticular joint subluxation. In this case the injury is almost a complete dislocation, but the articular processes are not over riding and reduction is therefore possible by simple extension.

A simple felt surgical collar should be worn for a few weeks An adequate support may be improvised from a man's stiff double collar opened to its full width, bound with wool and bandaged round the neck. Pain and stiffness sometimes persist owing to secondary adhesion formation especially when there has been osteoarthritic change in the joints. In many cases of cervical osteo-arthritis the pain referred to the arm and along the occipital nerves to the head is due to adhesions rather than to active arthritis and may be relieved by manipulation It is for this reason that osteopaths sometimes cure headache by manipulating the neck.

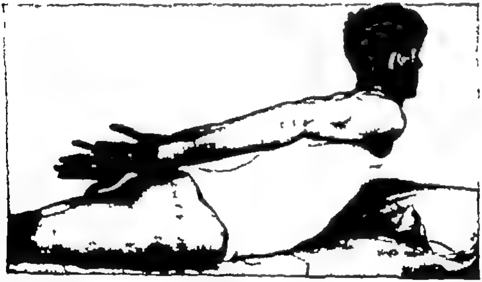
Subluxation or momentary dislocation of the cervical joints—Interarticular joint subluxation is more frequent and more serious than is generally recognised It is a type of dislocation of the neck, and the only feature distinguishing it from complete dislocation is that the articular processes have not actually overridden. In many cases the displacement is reduced spontaneously by simple extension movement and for this reason the injury is often overlooked There may be hæmorrhage round the cord paraplegia

FIG. 1515

Correctly applied plaster extending from the groins and symphysis pubis to the clavicles. The lumbar spine cannot be flexed.

FIG. 1516

Incorrectly applied plaster. It is cut too high at the groins and too low over the chest. Displacement of the fracture will recur.



FIGS. 1517 1518

Exercises for the spinal and abdominal muscles are practised regularly throughout the period of immobilisation.

and death, apparently with no bone injury. The subluxation can only be excluded by taking radiographs in the flexed position. Even if there is no danger of cord injury, failure to immobilise the joints for an adequate period may cause recurrent subluxation. Nerve root irritation and compression then lead to persistent disabling neuritis in one or both upper limbs.

Etiology—The displacement may follow a severe injury such as a fall on the head or a dive into shallow water. In other instances the accident appears unimportant. I have seen two such injuries occur from an involuntary forward jerk of the head sustained by a passenger in a car which stopped suddenly and unexpectedly.

Radiographic diagnosis—Forward tilting of the upper articular process so that its joint surface is no longer parallel with the process below is

Fig. 1531.

Reduction of cervical injuries from hyperflexion. Plaster is applied over the head, neck and chest to the pelvis, with the cervical spine fully extended. (*By courtesy of "Jour. Bone and Joint Surg."*)

sometimes obvious in routine lateral radiographs. The upper vertebral body may show slight forward displacement, or there may be narrowing of the front of the intervertebral disc. The displacement may be recognisable only when the neck is x-rayed in moderate flexion.

Treatment—Complete plaster immobilisation is essential. The neck is fully extended and plaster is applied by the technique shown in Figure 1531. Immobilisation should be continued for not less than two months. Referred root pain usually subsides within a few days. If pain recurs after removal of the plaster, a collar limiting forward flexion may be worn for a few weeks and then discarded for increasing periods every day. Pain persisting after several months may be due to adhesion formation, but recurrent subluxation must be excluded before the neck is manipulated.

Recurrent subluxation of cervical interarticular joints—If the injury is overlooked, or treated without complete immobilisation in the early stages, the ligaments do not fully tighten. There is recurrent subluxation with

Other methods of achieving extension of the spine have been devised.[1-4] The prone patient may be supported on a sling or hammock or on the canvas of a Rogers frame or the supine patient is laid on curved strips of metal or on the kidney bars of an operation table (Figs 1512 1513) The important principle of the two-table method is that the trunk sags to its own normal limit of extension not being forced beyond it by appliances The technique of Davis [4] achieved similar extension by slinging the feet from an overhead pulley but this is not now generally used (Fig 1514)

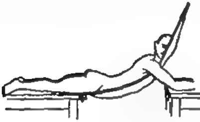


FIG 1512

FIG. 1513

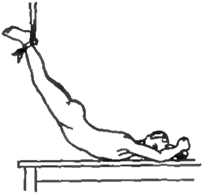


FIG 1514

Other methods of reducing fractures of the spine by hyperextension

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Davis, A. G *J Bone Joint Surg.*, 1929 11 133; and 1938 20, 429
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Johnson, H. F "Compression Fracture of the Spine." *Nebraska State med J* 1937 2, 1.

persistent *local* and referred pain The displacement is shown if lateral radiographs are taken with the spine in flexion (Fig 1532)

Treatment—Conservative treatment may be worth a trial The spine is immobilised in plaster in full extension for four months If the displacement and root pain return after removal of the plaster operative fusion and bone

FIG 1532

FIG 1533

Recurrent interarticular joint subluxation. Three years after injury there is still severe root pain (Fig 1532) After extension of the neck and operative fusion the symptoms were relieved (Fig 1533)

FIG 1534

FIG 1535

Recurrent interarticular joint subluxation after operative fusion with tibial bone graft, showing the range of movement that is possible (same case shown in Figures 1532 1533)

grafting are necessary A graft from the crest of the ilium is implanted on to the laminæ and bases of the spinous processes The fusion must be as local as possible in order to minimise subsequent stiffness of the neck (Figs 1534-1535) After operation the neck and head are immobilised in plaster for about four months until there is sound consolidation by bone

Fig 1515

Correctly applied plaster extending from the groins and symphysis pubis to the clavicles. The lumbar spine cannot be flexed

Fig 1516

Incorrectly applied plaster It is cut too high at the groins and too low over the chest. Displacement of the fracture will recur

Figs. 1517 1518

Exercises for the spinal and abdominal muscles are practised regularly throughout the period of immobilisation.

CRUSH FRACTURE OF THE CERVICAL VERTEBRAL BODIES

Simple compression and comminuted fractures of the cervical vertebral bodies are less common than dislocations and fracture-dislocations The fifth sixth or seventh vertebræ may be crushed by forcible hyperflexion injuries It must be remembered that in these hyperflexion injuries with crushing of a cervical vertebral body there is always danger of acute prolapse of disc material which may compress and damage the cord[1] Protection in plaster is essential The fracture is treated as lumbar crush fractures are treated the displacement is reduced by hyperextension and the spine is immobilised in plaster

Treatment—A piece of strong wood three inches wide is nailed to a wooden table so that it projects ten or twelve inches from the end It is padded with wool (Fig 1531) The patient lies face upwards with the free end of the wood at the level of the cervico-dorsal junction The head is supported by an assistant in neutral rotation, and lowered until the neck is fully extended The arms are held aside while plaster is applied from the pelvis to the top of the head The plaster should extend over the forehead to the level of the eybrows, and it may then be cut away beneath the chin so that movements of the jaw and larynx are facilitated A window is cut over each ear Patients become surprisingly tolerant of their discomforts and within a few days they may be up and about normally dressed Immobilisation is continued for three months After removal of the plaster normal function is rapidly restored by active exercises A protective collar or splint is of no real value and moreover it may prove difficult to persuade the patient to discard it

DISLOCATION OF THE CERVICAL JOINTS FROM FLEXION INJURY

When forward displacement of the upper segment of the spine is more marked the articular processes on one or both sides slip forwards over the articular processes below The processes are locked in this position and the dislocation cannot possibly be reduced by simple extension movement In many cases the lower vertebral body is crushed or an anterior marginal fragment is broken off and displaced forwards As a rule the spinal cord is contused or compressed and there is paraplegia

Treatment—It is useless to attempt the reduction of a complete unilateral or bilateral interarticular joint dislocation by simple extension of the spine The various manipulative procedures that have been described[2,3] also fail in many cases Strong traction is necessary It must be carefully controlled and slowly increased until the articular processes are disengaged The spine is then extended and the traction is reduced to a weight of a few pounds There is always danger of redisplacement[4] especially when the facets are fractured so that skull traction should be continued for several weeks, with plaster immobilisation for some weeks longer

Until recent years the only available method of applying continuous traction to the neck was by a Glisson's sling which takes its purchase from

Barnes, R. "Paraplegia in Cervical Spine Injuries." *J Bone Joint Surg.*, 1948, 30, 230
Walton, G. L. "New Method of Reducing Cervical Dislocations." *J nerv ment Dis.*, 1893, 20, 600
Walton, G L. "Further Observations on Cervical Dislocation." *Boston med Surg J.*, 1903, 149 445
Soto-Hall, R "Recurrence in Dislocation of Cervical Spine" *J Bone Joint Surg* 1935, 17 902.

FIG 1519

This patient never stops to think that "his back is broken. He is playing deck tennis and is too full of the joys of life to develop functional complications.

FIG 1520

Six patients with fractures of the spine assisting each other to redevelop the spinal musculature. Such grouping encourages a spirit of competition and rivalry It is the lone patient, left to himself, who becomes introspective.

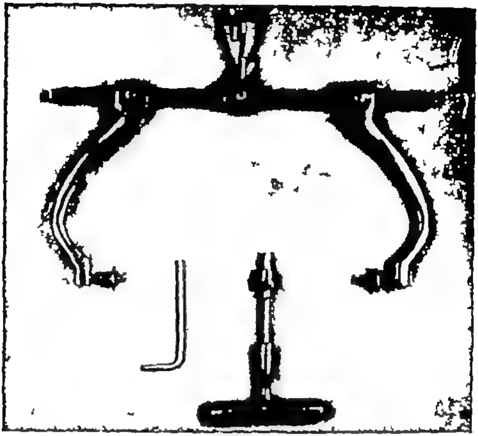


FIG 1336

Skull callipers for skeletal traction of the cervical spine, with locking key and small trephine.

FIG 1337

Skull traction using the callipers shown in Figure 1336. Within a few hours the cervical dislocation is corrected and the weights are reduced. (In this case the callipers have been inserted too far forward The calliper points should lie in a vertical plane passing through the centre of the external ears, where the bone is thicker and there is less risk of perforating the inner table of the skull.)

FIG 1521
Exercises are continued in the gymnasium. This patient, who is climbing wall bars, is approaching the end of his four months immobilisation as shown by the looseness of the plaster jacket.

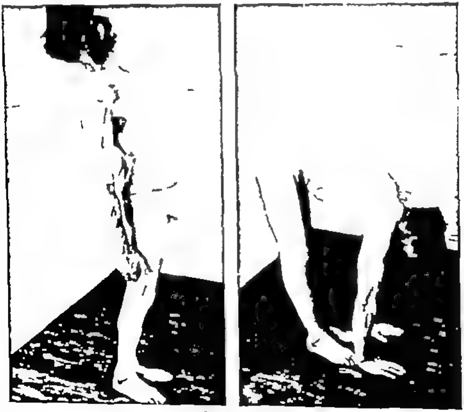


FIG 1522
Range of movement in a man aged fifty five after a crush fracture of the spine immobilised in hyperextension for five months. Even in the elderly patient, immobilisation in hyperextension does not cause permanent stiffness.

beneath the chin and the occiput This method is extremely uncomfortable and may be responsible for receding of the lower jaw with disfigurement Skeletal traction is free from these complications

Skeletal traction by skull callipers—Skeletal traction from the skull may be maintained by heavy stainless steel wire fixed through double burr holes,

Fig 1538

Fig 1539

Fig. 1540

Fig 1541

Fig 1542

Fig 1543

Dislocation of interarticular and intervertebral joints (Fig 1538) Skull traction was applied (Fig 1539) When the over riding of articular processes was corrected (Fig 1540) the pulley was lowered to extend the spine and the weight was then reduced (Figs. 1541 1543) After a few weeks the traction was discontinued and plaster applied.

by one of the various types of skull callipers or by the Roger Anderson calliper which is fixed beneath the zygoma on each side[1-4] A suitable type of skull calliper is shown in Figures 1536-1537 The callipers can be introduced under local anaesthesia without moving the patient from his bed. A one to one and a half inch incision is made on each side of the skull above the temporal lines and immediately above the auricles A small

Crutchfield, W G. "Skeletal Skull Traction." *South Surg* 1933 2, 156 *J Bone Joint Surg.*, 1938, 20, 696.
McKenzie, K. G. "Fracture-dislocation of the Spine." *Canad. med. Ass J.*, 1935, 32, 263.
Hoen, T I. "Skeletal Traction for Cervical Fracture-dislocation." *Arch. Neurol. Psychiat Chicago*, 1936, 36, 158.
Barton, L. G "Cervical Fracture-dislocation—Skeletal Traction." *Surg Gyn. Obstet.*, 1938, 67 94.

FIG 1523

Application of plaster jacket with head traction. A plaster may also be applied with the patient sitting up in his bed which is wheeled under the head traction apparatus. This technique is clearly better than the two-table method for applying a jacket when a fracture has been produced by hyperextension (p 967) A few surgeons use it even for vertebral fractures caused by flexion (p. 963) It should be understood that the patient is not actually suspended; his toes are still on the ground.

hole is cut with a trephine through the outer table of the skull. Penetration of the points of the calliper can be controlled by a flange on a screw thread adjusted according to the thickness of the bone The points are hooked under the bone margin and lie between the two tables The legs of the callipers are then locked and attached to a cord which passes over a pulley at the head of the bed to a weight The head of the bed is raised on blocks. The pulley should be free to slide from side to side of the crossbar in order to facilitate movement and nursing of the patient As a rule traction should begin with a weight of about fifteen or twenty pounds Check x rays are

Fig 1544

Two months old unreduced cervical dislocation with interlocked articular processes.

taken every fifteen minutes until the articular processes are disengaged (Figs 1538-1543) The crossbar carrying the pulley is then lowered so that the cervical spine is extended When radiographs show that the articular processes are in accurate apposition the weight may be reduced to ten pounds Traction is continued for three or four weeks until the general condition of the patient permits the application of a plaster cast If the articular processes are fractured and the reduction is unstable traction may be continued for six or eight weeks

Case of two months old cervical dislocation with Brown Séquard paralysis —*Reduction by skull traction and facetectomy*—A farmer aged thirty five in attempting to stop a runaway horse fell beneath the wheels of the cart

Application of plaster jacket, not with the spine hyperextended, but in the neutral position with light traction—A plaster jacket can be applied with light vertical traction in the neutral position of the trunk without any hyperextension (Fig 1623) This does not correct wedging of the compressed vertebral bodies Nevertheless some surgeons believe that immobilisation in hyperextension causes persistent lumbo-sacral pain and deliberately immobilise the trunk in the neutral position even although slight compression is left uncorrected, they think that recovery is accelerated without any disability arising. It is of course evident that fractures produced by hyperextension should be immobilised in this way and not in a hyperextension plaster (page 967)

TREATMENT OF COMMINUTED LUMBO-DORSAL FRACTURES BY EARLY SPINAL FUSION

When there is avulsion of the interspinous ligaments and rupture of the ligaments of the joints so that compression fracture of the intervertebral body is unstable and especially when there is comminution of the vertebral body with destruction of the intervening discs protection and immobilisation is still more important In these cases it is seldom enough just to immobilise the spine in a plaster jacket even for as long as three or four months because even after that the displacement recurs and traumatic arthritis develops in the intervertebral joints It is better to be ready to do an early fusion of the two affected vertebræ through a posterior approach using cancellous bone grafts cut from the ilium The first essential step of the operation is to localise the level of fracture with precision This may seem obvious but it is surprising how difficult it is to be certain of the levels when the spinous processes are exposed through a posterior midline incision The fusion must be restricted to the two vertebræ involved (or in the occasional case where there is damage to the intervertebral joints below as well as above to the three vertebræ involved). When the spinous processes are exposed a small nail or screw should be driven into the one that is believed to correspond to the crushed vertebral body Lateral radiographs should then be taken in order to confirm that it is in fact so When the surgeon is quite sure that the level of exposure is right the lamina and spinous processes should be rawed and freshened the cartilage of the lateral joint being removed and bone chips cut from the ilium implanted In these fractures where the spinal cord has escaped damage there is no need to use the internal fixation of a plate or screws A plaster jacket is applied which is kept in position for not less than three or four months A method of spinal grafting was often advocated in which the patient is simply put back to bed without any external protection or support and allowed to get up within a few weeks It may be more comfortable for the time being but it is so unreliable and is associated so frequently with failure of sound fusion that it is unwise

TREATMENT OF INTERLOCKED LUMBO-DORSAL FRACTURES BY OPERATIVE REDUCTION

There is an important group of fracture-dislocations of the lumbar spine in which it is unsafe to attempt simple postural reduction by hyperextension When the displacement is produced by a twisting injury with rupture of

and at once complained of pain in the neck, numbness and tingling of both arms, and loss of power in the legs He was carried to a hospital where radiographs showed a fracture of the sixth cervical spinous process The vertebræ below this level were concealed by the shadow of the shoulder A plaster collar was applied, but tingling persisted After several weeks

Fig 1545
Reduction of dislocation after heavy skull traction for six days and facetectomy on one side.

head traction was arranged by a Glisson's sling below the chin Two months after the accident radiographs at the Liverpool Royal Infirmary showed a dislocation between the sixth and seventh cervical vertebræ with over riding of the articular processes (Fig 1544) Callus formation beneath the anterior ligament was already fusing the vertebræ in their displaced position Loss of sensation in the right lower limb abdomen and lower chest and exaggeration of the reflexes of the left leg with ankle clonus and loss of power were evidence of injury to the left side of the cord (Brown-Séquard syndrome)

Skull callipers were applied with twenty pounds weight extension The neurological signs were kept under close observation x ray examination was repeated daily, and the traction was slowly increased (Figs 1546-1553) On the fifth day when the traction amounted to forty pounds the articular processes slipped into position on the left side On the right, the two

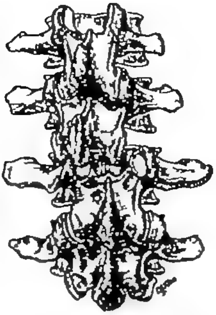
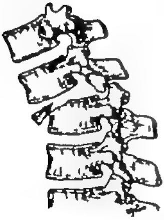


FIG 1524

Locking of articular processes in lumbar fracture-dislocation with locked facets from rotatory displacement.



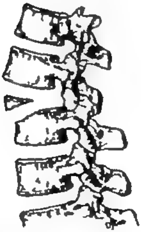


FIG 1525 FIG 1526 FIG 1527

Lumbar fracture-dislocation with locking of articular processes (Fig 1525) If the spine is simply hyperextended the upper process cannot slide back, the vertebræ are forced apart and the cord injury may be increased by stretching (Fig. 1526) Operative replacement is imperative. It may be necessary to excise the lower articular process (Fig 1527)

(By courtesy of "Jour Bone and Joint Surg")

Fig 1546
Two months old unreduced dislocation.

Fig. 1547
First day—20 lb. skull traction

Fig 1548
Second day—25 lb. skull traction.

Fig. 1549
Third day—30 lb skull traction.

Reduction of old cervical dislocation by skull traction and facetectomy

Fig 1650
Fourth day—33 lb skull traction

Fig 1651
Fifth day—40 lb skull traction.

Fig 1652
Sixth day—40 lb skull traction with oblique pull.

Fig 1653
Seventh day—immediately after facetectomy—12 lb skull traction

Reduction of old cervical dislocation by skull traction and facetectomy

FIG 1563

Fracture-dislocation at the eighth thoracic level with spinal cord injury

FIG 1564

After reduction of the displacement by hyperextension the patient was supported in a plaster bed with an anterior plaster cast, and was turned regularly every two hours (Watson-Jones, R., *Brit med J* 1936, 1, 130). Recovery was complete. It is now accepted that turning every two hours is essential, but that plaster casts may be dangerous.

processes appeared to be firmly fused despite an oblique pull concentrated on that side, they could not be replaced. Distraction of the vertebral bodies had already reached the limit of safety so that on the seventh day facetectomy was performed [1] The laminæ were exposed by a posterior midline incision and the upper half of the right superior articular process of the seventh vertebra was excised. Radiographs taken immediately after operation showed accurate replacement and the traction was then reduced to twelve pounds weight After four weeks the callipers were removed Immobilisation was continued for two months by a plaster collar and jacket The sensory loss on the right side slowly receded and ultimately recovered but exaggeration of the reflexes persisted in the left leg

It is of interest to note the minor discomfort associated with heavy skull traction On the day that the weight was increased to forty pounds the patient raised his hand mirror cheerfully inspected the callipers in his skull and observed Anyone looking at this might think it would hurt, but it is just nothing to the strap —a reference to the Glisson chin sling That very day his wife presented him with a son, and I received a personal honour which I had always understood was reserved for gynaecologists, the son was christened Watson "

SUBLUXATION AND DISLOCATION OF THE CERVICAL JOINTS *FROM EXTENSION INJURY*

All the fractures and dislocations of the cervical spine discussed so far arise from forcible flexion of the neck. It must be understood however that a similar group of injuries can be sustained from forcible extension of the neck. Simple sprains are of no serious clinical significance and recovery is soon complete no matter what treatment is arranged On the other hand, exactly as with the corresponding flexion injury there may be momentary dislocation from hyperextension which undergoes spontaneous reduction so that when radiographs are taken the bones appear to be in normal relationship There may even have been complete severance of the spinal cord with paraplegia sustained at the moment of injury with radiographs showing an apparently normal relationship of the vertebral bodies and articular processes The spinal cord may be damaged by pressure of the interlaminar ligament (the ligamentum flavum) on the back of the cord,[2] or perhaps sometimes from displaced disc material at the front of the cord [3] These hyperextension displacements occur most commonly in elderly patients whose cervical joints are stiffened by senile change with intervertebral arthritis [4-6] The cervical spine being less elastic than normal, is less able to withstand stresses so that the anterior common ligament ruptures, the intervertebral disc is damaged and the posterior ligaments are more readily displaced within the lumen of the spinal canal

Facetectomy in dislocations of the cervical spine—Paiva Chaves of Lisbon recommends facetectomy in cervical dislocations almost as a routine procedure, in order to avoid the need for heavy skull traction—" Separata da Revista, Clinica Contemporanea, 1946, 1, 274.

Taylor A. R. " Mechanism of Injury of the Spinal Cord in the Neck without Injury to the Vertebral Column. J Bone Joint Surg 1951, 33, 543.
Barnes, R. " Mechanism of Cord Injury without Vertebral Dislocation." Editorial, J Bone Joint Surg. 1951 33, 495.
Morton, S. A. " Localised Hypertrophic Changes in the Cervical Spine with Compression of the Spinal Cord or of its Roots." J Bone Joint Surg 1936, 18, 893.
Barnes, R. Paraplegia and Cervical Spine Injuries." J Bone Joint Surg 1948, 30, 234
Taylor A. R., and Blackwood, W " Paraplegia in Hyperextension Cervical Injuries with Normal Radiographic Appearances." J Bone Joint Surg., 1948, 30, 245.

Despite the desperate difficulties the psychological setbacks and the prodigious problems which must at first seem almost insoluble these patients with undying spirit aided by nurses and physiotherapists with undying devotion no longer go quickly and miserably to the grave They make useful service to the community and they make it happily Surely this is one of the miracles of modern surgery

EMERGENCY TREATMENT OF FRACTURES OF THE SPINE WITH PARAPLEGIA

Admit at once to a special centre—The first important duty of a doctor called to see a patient with fracture-dislocation of the spine and paraplegia is to arrange prompt admission to a centre where special arrangements exist It may be that there is no such centre nearby—but it is better that the patient should lie in an ambulance driven carefully and slowly for fifty or a hundred miles or in more remote areas be transported by air than that the precious first few days should be wasted in a local hospital where there are no special facilities and where none of the staff has special experience I know of the general public opinion—get him into a hospital bed as quickly as possible no matter what hospital but do it quickly—and how wrong that is! I know also that specialised centres have not yet been developed fully in all parts of the world But where there is a specialised centre within 100 or 1 000 miles the patient should be transferred to it within the first forty-eight hours after injury

Movement of the patient in emergency treatment—In moving a patient with spinal injury and paralysis from where he lies to a stretcher ambulance or aeroplane the essential principle of first-aid treatment is to keep the spine in the neutral position neither forcibly flexed nor forcibly extended It is dangerous to lift a patient who is lying on his back by the shoulders and hips because the spine then sags between the points of support and the forced flexion that results may crush the spinal cord If the patient is in a prone or face-down position such lifting is relatively harmless because the spinal column is extended, and in most fracture-dislocations extension of the spine reduces the displacement and relieves compression of the cord Long ago I urged face-down transportation of all patients with suspected spinal injury [1] But there is sometimes danger if the spine is forcibly extended especially in lumbar fracture-dislocations with interlocked facets, and also in many cervical injuries Thus the first-aid worker should do all he can to keep the spine straight neither flexed nor extended If possible a flat board or stretcher should be placed alongside the patient who is lifted on to it by many assistants taking support of the head, neck thoracic lumbar pelvic and thigh regions keeping the spine in the rigidly neutral position throughout the lifting Once the patient is on the stretcher he should not again be lifted from it until surgical and radiographic examination has disclosed the exact site of injury and the type of displacement

Emergency nursing of the patient—If it is not possible to arrange immediate admission to a special paraplegic unit the nursing should be arranged just as it will be when the patient is admitted to such a centre—that is to say

[1] Watson-Jones R. *Brit med J* 1931, 1, 300 1932, 1, 694 1932, 1 888 1933, 2, 940; 1933, 2, 1141 1934 2, 1012 1939 1 130

It must be recognised that, as momentary dislocations produced by flexion are concealed in x rays taken in the neutral position but are revealed when the examination is repeated with the neck gently flexed, so these injuries are concealed in lateral radiographs in the neutral position but may be disclosed if the spine is gently extended Even apart from such special x ray projections it is usually possible by careful clinical examination to detect an abrasion or laceration of the face or forehead in hyperextension injuries and of the vertex of the head in hyperflexion injuries

It is also evident from this important group of cases that the extended position of the neck is by no means to be regarded as always safe In first-aid treatment and also in early management of the case before investigations are complete the neck must be kept in the neutral position —neither flexed nor extended. In treatment there is no need for calliper traction from the skull Furthermore provided that there is care to avoid any excessive range of movement during the first few weeks, there is seldom need for immobilisation in plaster It is often wise to use a light felt collar or a simple plaster slab moulded over a layer of felt, by which to protect the joint during the first few weeks

FRACTURES AND DISLOCATIONS OF THE ATLAS

Fracture of the atlas—The usual cause of fracture of the atlas is a fall on the head from a height The blow is transmitted from the skull through the two lateral masses of the atlas which are forced apart so that the bone

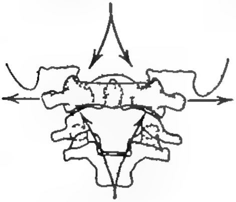


Fig 1554

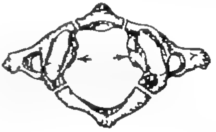


Fig 1555

Fracture of the atlas due to a fall on the head. The force is transmitted through the lateral masses which are driven apart so that the arch fractures at its weakest point. (*Diagrams adapted from those first published by Jefferson, G., "Brit. J Surg* 1920, 7 416.)

fractures at one of the weak points represented by the anterior or more commonly the posterior arch [1] (Figs 1554-1555) There is no cord lesion in at least 50 per cent of cases and the injury is by no means necessarily fatal

Clinical features [2]—There is spasm of the neck muscles and the patient holds himself rigidly as if balancing a weight upon his head When getting up from recumbency or with any other change of position the patient usually supports his head with his hands. Nodding and rotation movements are

[1] Jefferson, G "Fracture of Atlas Vertebra" (with review of recorded cases). *Brit. J Surg.* 1920, 7 407
[2] Grogono, B. J S. "Injuries of the Atlas and Axis." *J Bone Joint Surg* 1954, 36-B, 397

with many pillows, at least ten or a dozen, supporting the curves of the spine in a neutral or slightly extended position and separating the lower limbs from each other in order to prevent pressure contact (Figs 1571 1574) The patient should be rolled carefully from one position to another, first to the left then to the right sometimes on the back and also on the face repeated regularly every two hours throughout the day and night This is important because pressure ulceration of insensitive areas can arise overnight A plaster jacket or plaster bed should not be used It is now proved beyond doubt that plaster immobilisation even for two or three days carries with it a risk of pressure ulceration of the skin and subcutaneous tissues so great as to increase the mortality by at least 10 per cent

Emergency management of the paralysed bladder—In emergency treatment there need be no anxiety about the paralysed bladder The output of urine is greatly reduced by shock Moreover even if the bladder does become distended with overflow incontinence no harm arises for at least forty-eight hours or more It is only when the bladder is left persistently distended for many days or weeks that complications arise Leave the bladder alone or at the most assist overflow by gentle abdominal compression perhaps also with the pressure of a finger in the rectum Do not be tempted into using a catheter unless it can be introduced by perfect aseptic technique The catheter must not be touched by hand The demands of asepsis are no less great than in any major surgical operation Do not perform suprapubic cystotomy as an emergency procedure Leave the bladder alone, it will look after itself for a few days especially if the head of the bed is raised

General constitutional treatment—The usual measures of treatment for shock should be instituted. Fluid intake should be increased to six or eight pints daily It may be wise to prevent hypoproteinæmia by insisting on a diet of 3 000 calories daily including 150 grammes of protein made up by adding cheese and meat also giving iron in the form of ferrous sulphate thrice daily as well as vitamin B complex and vitamin C

PATHOLOGY OF SPINAL FRACTURES WITH PARAPLEGIA

After emergency treatment wherever it may have been carried out the patient should have been transferred to a special centre within twenty four to forty-eight hours In the special centre immediate clinical and radiographic investigation will establish the level and type of injury to the spinal cord and nerve roots Before outlining these investigations, upon which the treatment is wholly dependent we must consider the neuropathology of spinal cord and nerve root injuries and distinguish four clinical types

FOUR TYPES OF SPINAL CORD AND NERVE ROOT INJURY

Fracture-dislocations of the vertebræ may be associated with injury to the spinal cord and nerve roots from simple contusion and concussion or by actual compression or crushing amounting to transection The compressing force may be the displaced vertebral bodies or laminæ or sometimes the displaced intervertebral disc material in front or the displaced ligamenta flava behind These details of pathological anatomy are relatively unimportant It suffices to say that the cord or nerve roots may be injured

limited There may be pain and sometimes anæsthesia in the area supplied by the great occipital nerve

Treatment—If there is paraplegia skeletal skull traction should be used for several weeks If there is no complication the neck is immobilised in plaster with the head in the mid position for three months

Dislocation of the atlas—The stability of the atlas depends upon the transverse ligament which lies between the lateral masses and braces the odontoid process to its anterior arch. If the ligament is torn the atlas can dislocate forwards Similarly if the base of the odontoid process is fractured the atlas and the odontoid fragment may be displaced together Dislocation is more serious than fracture-dislocation, because if the odontoid is intact the spinal cord is in danger of being crushed against it (Figs 1556-1557) When there is less marked displacement and the cord escapes injury the clinical picture resembles that of fracture of the atlas but as a rule there is also rotatory displacement of the head The bone must be replaced, with care to protect the spinal cord by preventing flexion or rotation movement of

Fig 1556

Fig 1557

Forward dislocation (Fig. 1556) and fracture-dislocation (Fig 1557) *of atlas*. If the odontoid is displaced forwards there is less danger of cord compression and the patient often survives.

the patient s head during induction of anæsthesia A plaster cast is applied with the neck fully extended and the head in neutral rotation the cast taking a purchase across the front of the forehead and also being moulded under the chin. If in succeeding weeks, it becomes loose enough to permit rotation movements a new cast is applied. Immobilisation is continued for three months It is then safe to begin active exercises and within a few weeks to encourage more energetic rehabilitation by which to restore the patient s confidence in his recovery (see Preface Volume I)

Unreduced dislocation of the atlas—If a dislocation of the atlas is overlooked considerable displacement may be observed months or years after injury Sometimes a perilous degree of displacement becomes firmly stabilised by scar tissue but in other cases the transverse ligament is weak and attenuated displacement is progressive and paraplegia may develop from late compression of the cord. If there is radiographic evidence of increasing deformity or neurological evidence of pressure on the cord spinal fusion must be undertaken The spinous processes and laminæ of the first three cervical vertebræ are exposed and freshened by the *Hibbs technique*

by the pressure of bone disc or ligament The clinical and radiographic study upon which treatment will be based must distinguish paralysis from 1) concussion of the spinal cord 2) crushing of the spinal cord 3) crushing of the nerve roots 4) crushing of both the spinal cord and the nerve roots

1. Concussion of the spinal cord—Momentary displacement of the vertebræ or of the discs or ligaments may cause spinal concussion sometimes with hæmorrhage or œdema but *without actual destruction of* the nerve fibres or nerve cells This causes motor sensory and visceral paralysis but the loss is seldom complete and there is nearly always evidence of some recovery within a few hours If from the beginning or at least within a few hours there is still total loss of sensation, loss of vibration sense which is even more important and loss of motor power it may safely be assumed that the symptoms are arising not from concussion alone—there must also be destruction of the cord.

2. Crushing of the cord (*transection*)—If the spinal cord is crushed or severed in the mid thoracic area there will be complete loss of sensation with paralysis of muscles, absence of muscle reflexes and lack of normal control of the bladder and rectum These injuries are at first associated with spinal shock, and reflex activity in the distal part of the cord is partly or wholly suppressed . The paralysis of muscles is flaccid and the reflexes are usually absent There is no reflex activity of the bladder, and retention of urine causes distension with overflow incontinence Spinal shock passes off fairly quickly in lower animals but it may persist for several days or weeks in the human Only then does the part of the cord below the level of injury resume reflex function with the simple uncontrolled responses of a spinal animal or Sherrington s decerebrate animal [1]

The separated distal part of the spinal cord then behaves on its own without over riding control from higher centres No longer are the paralysed muscles flaccid they are spastic Any stimulus such as an unexpected touch or pressure applied to the lower limbs may cause widespread spastic movement or mass-reflex in which the adductor muscles overpower the other muscles of the hip the hamstrings overpower the extensors of the knee and the calf muscles overpower the dorsiflexors of the ankle These spasms may even be initiated by the simple irritability of pressure sores or by the stimulus of an over full bladder or distended rectum In consequence of the spastic imbalance of muscles contractures tend to develop in the adductors of the hip the flexors of the knee and the plantar flexors of the ankle The function of the bladder becomes entirely reflex—it is an automatic or cord bladder Afferent stimuli to the skin in the region of the groins or penis give rise to unconscious emptying of the bladder corresponding with the state in infancy before higher cerebral control of the bladder reflex at the second and third sacral segments has developed

If there is sensory and motor paralysis of the trunk and lower limbs no matter how irregularly distributed the persistence or reappearance of reflex activity in the lower limbs indicates that the distal part of the spinal cord has been separated from cerebral control by severance of the cord Such reflex activity indicates interruption of the spinal tracts Of these reflexes, the three most important are 1) the anal reflex—a stimulus to the perineum

[1] Sherrington, C. S. "The Integrative Action of the Nervous System." Harvard University Press, 1906.

Grafts are inlaid and fixed to the occipital bone as described by Cone and Turner [1] The exposure of this region is difficult, hæmorrhage is not easily controlled, and the operation is one of considerable magnitude

Spontaneous dislocation of the atlas—A girl, aged sixteen, was suffering from tuberculous cervical glands with secondary infection One day a nurse was dressing the sinuses and in order to gain better access she asked the patient to turn her head She assisted her by pushing her chin, the girl choked, became cyanosed and was dead [2] This was an example of spontaneous dislocation of the atlas, the result of decalcification of bone in response to neighbouring infection and consequent loosening of the attachment of the transverse ligament

Spontaneous dislocation of the atlas causing sudden death is rare, but spontaneous subluxation with acquired torticollis is more frequent [3,4] It nearly always occurs in children aged from six to twelve years, and it may complicate any infection in the upper part of the neck Many such displacements have occurred after tonsillitis and some after nasopharyngitis, retropharyngeal abscess, tuberculous adenitis, acute mastoid infection and osteomyelitis of the occipital bone About a week after the onset of infection the child complains of a crick in the neck The head is held rigidly in the position of torticollis, but there is no contracture or spasm of the sternomastoid; the rigidity and deformity are due to spasm of the deep cervical muscles Radiographs show forward and rotatory displacement of the atlas The displacement should be reduced under anæsthesia Plaster is applied with the head in neutral rotation and extension Recumbency, skull traction or chin traction are unnecessary After the primary focus of infection has healed, immobilisation is continued for ten weeks A removable collar may be used for two or three weeks longer until a full range of painless movement is regained

It should be understood very clearly that these spontaneous subluxations of the atlas in children arising in consequence of the hyperæmia of neighbouring infection are very seldom dangerous, and that perfect recovery may almost always be expected from the simple conservative treatment of correcting the position of the head under anæsthesia and applying a closely fitting plaster to the head, neck and upper chest It should be emphasised however that the plaster must fit closely, it must extend over the forehead almost to the eyebrows and be well fitted under the chin and over both sides of the face, holes being cut out for the ears In a recent contribution Grogono [5] reported two such cases in children, one aged four years and the other aged ten years, where it is said that displacement recurred on one or more occasions despite immobilisation in plaster, so that an operation was undertaken by which to fuse the spinous process of the atlas and axis with cancellous grafts and wiring It is not at all easy to believe that so difficult an operative procedure is really needed in this simple condition and I would emphasise that, although success may always be expected from

[1] Cone, W, and Turner, W G "Treatment of Cervical Fracture Dislocations by Skeletal Traction and Fusion." *J Bone Joint Surg*, 1937, 19, 584
[2] Reid, quoted by Greig "Clinical Observations on the Surgical Pathology of Bone." Edinburgh, 1931.
[3] Watson-Jones, R "Spontaneous Hyperæmic Dislocation of the Atlas." *Proc R Soc Med* (Section of Orthopædics, 34) 1932, 25, 586.
[4] Watson-Jones, R, and Roberts, R. E. "Calcification, Decalcification and Ossification" (review of reported cases of spontaneous dislocation of the atlas). *Brit J Surg* 1934 21 476.
[5] Grogono, B. J "Injuries of the Atlas and Axis" (spontaneous dislocation of the atlas) *J Bone Joint Surg* 1954 36-B, 401

causes contraction of the anal muscles, 2) the glans-bulbar reflex—friction or compression of the glans penis causes contraction in the bulbo-cavernosus muscles in the perineum, 3) the extensor plantar response—a stimulus to the sole of the foot causes dorsiflexion of the great toe After transection of the cord even despite spinal shock one or more of these reflexes reappear quite early, or indeed they may never disappear at all Thus it is usually possible to know within a few hours, from the association of motor and sensory paralysis with the existence of such reflexes that the spinal cord has been crushed

3 **Crushing of nerve roots and of the cauda equina**—Whereas the non medullated nerve tracts of the spinal cord are incapable of regeneration after they have been severed, there may be complete recovery from injury to the nerve roots or cauda equina regeneration occurring just as it does in any other injured peripheral nerve A fracture-dislocation of the spine below the level of the second lumbar vertebra can injure only the roots of the cauda equina (although in fact there is so much room within the lumen of the lumbar spinal canal that these nerve roots are seldom damaged) If by chance the nerve roots of the cauda equina are severed there will be complete loss of motor power, loss of sensation, abolition of reflexes, and an isolated or autonomous bladder which is partly but not completely emptied by local myoneural activity If regeneration fails, with permanent motor and sensory paralysis the muscles remain flaccid There is no spasticity because there is no reflex control from the lower part of the spinal cord. The isolated bladder remains autonomous without reflex activity and it empties imperfectly by the simple local reflex initiated by stretching of the bladder muscles

4. **Crushing of both the cord and nerve roots at the thoraco-lumbar junction**—The most common site of fracture-dislocation of the spine with nerve injury is at the thoraco-lumbar junction, where the lumbar and sacral segments of the spinal cord are concentrated at a level from the tenth thoracic to the first lumbar vertebræ The spinal column is much shorter than the vertebral column it terminates as the conus medullaris at the lower margin of the first lumbar vertebra Above the tenth thoracic vertebra the segments of the cord and the emerging nerve roots lie more closely to the level of the corresponding vertebral bodies than at the thoraco lumbar junction At the tenth thoracic to the first lumbar vertebræ there lie side by side the lumbar and sacral segments of the cord and all the lumbar and sacral nerve roots Below the second lumbar vertebra there are only nerve roots with no spinal cord segments

At this level of the thoraco-lumbar junction of the spine vertebral fractures and fracture-dislocations may 1) transect the cord and leave the nerve roots intact 2) transect the cord and injure some of the nerve roots 3) transect the cord and injure all the nerve roots Whereas there can be no recovery from transection of the spinal cord or injury of the conus medullaris there can be recovery from injury to the nerve roots The preservation or regeneration of these lumbar roots may permit recovery of important groups of muscles controlling movement of the hip and knee joints upon which the patient may be utterly dependent for his ability to walk well or even to walk at all Protection of the lumbar nerve roots in injuries at the thoraco-lumbar junction is of vital significance It is clearly

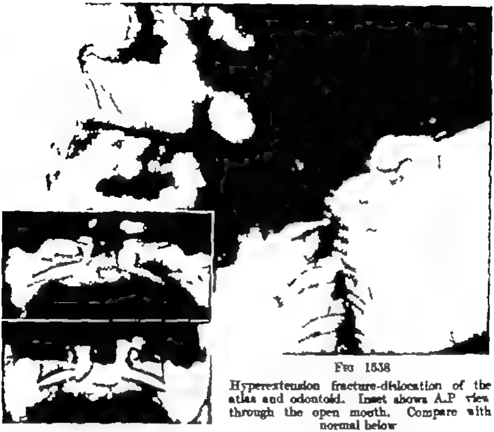


Fig 1538

Hyperextension fracture-dislocation of the atlas and odontoid. Inset shows A.P view through the open mouth. Compare with normal below

Fig 1539

The dislocation was reduced but the patient was elderly and plaster could not be tolerated A block leather collar was used

important that an early distinction should be made between irrecoverable injuries of the spinal cord and recoverable injuries of the lumbar nerve roots which lie alongside

CLINICAL, RADIOGRAPHIC AND NEUROLOGICAL STUDY OF PATIENTS WITH TRAUMATIC PARAPLEGIA

Radiographic examination—Radiographs should first be taken to determine the level of injury to the vertebral bodies and intervertebral joints This can usually be accepted as the level of injury to the spinal cord and nerve roots (there is sometimes spreading œdema or hæmorrhage above as well as below the level of cord injury but the neurological picture is seldom altered materially thereby) It has already been emphasised that the displacement of a fractured vertebral body shown in radiographs does not necessarily represent the displacement occurring momentarily when violence was sustained. Some correction or even complete reduction often occurs spontaneously when the patient is laid flat on the ground or on a stretcher Radiographs of a fractured spine must therefore be interpreted with caution We must recognise not only the displacement that may be obvious but also the potential displacement which is perhaps concealed by spontaneous reduction Moreover there is often rotational displacement of the spine without obvious evidence of gross displacement in radiographs Figure 1565 seems to show a simple and apparently harmless compression fracture of one lumbar vertebra and yet careful examination of the antero-posterior projection seen in Figure 1566 proves that there has been fracture of the facets on the right side with disruption of the apophyseal joint This rotational type of fracture-dislocation is shown still more clearly in Figure 1567 where there is a slice fracture of the first lumbar vertebra with clear evidence of twisting injury in the dislocation of the left twelfth rib and the fracture of the first left lumbar transverse process

Figure 1568 shows a fracture-dislocation from rotational stress with interlocking of the articular facets If such a vertebral fracture-dislocation is treated conservatively by the two-table method or by any method of reduction by hyperextension of the spine the hinging of articular processes on each other with consequent traction on the spinal cord and nerve roots may well produce paralysis

Neurological examination—Radiographic study must then be correlated with the clinical and neurological examination In fracture-dislocations of the mid thoracic region it will usually be found that the level of bone injury of the vertebræ as determined by x ray examination corresponds fairly accurately with the level of spinal cord injury as shown by the sensory and motor disturbance In fracture-dislocations at the thoraco lumbar junction it may be found that there is disparity in the level of bone injury as determined by x rays and the level of nerve injury as shown by neurological examination If this is so it means that although the cord has been damaged some nerve roots have been spared (Figs 1569-1570) The whole plan of treatment must then be to protect the intact nerve roots

Let us take a simple example If there is a fracture-dislocation of the spine as shown by x rays between the twelfth thoracic and first lumbar vertebræ, with presence of the anal and glans-bulbar reflexes proving

FIG 1421

Typical fracture of the neck of the talus with dislocation of the posterior half of the subtalar joint The outline in the pocket is cut accurately from the "distal fragment"—that is to say the head of the talus, calcaneum and other bones of the foot. Only when this is fully plantar flexed and displaced backwards are the tarsal bones in normal relationship Try the outline in every position, and finally in full plantar flexion (with its base in the position shown by two arrows). If the surgeon is not sure whether or not there is a subtalar dislocation, it is wise to take a tracing of the "distal fragment" on tissue paper and adjust it in relation to the body of the talus

FIG 1565

On first inspection this may appear to be a simple wedge compression fracture (though it is to be noted that the margin of the vertebra above is displaced slightly forwards on the compressed body) See below same projection in the antero-posterior plane.

FIG 1566

Same case as Figure 1565. Antero-posterior projections show clearly that this was a

FRACTURE OF THE NECK OF THE TALUS WITH SUBTALAR DISLOCATION AND POSTERIOR DISPLACEMENT OF THE BODY

The mechanism of injury and displacement was discussed on page 580 There is a fracture of the neck of the talus with backward displacement of the body which lies on the inner aspect of the tuber calcanei, rotated so that its fractured surface is directed laterally and with its medial tubercle hooked behind the sustentaculum tali (Figs 1422 1425) The treatment is often complicated by 1) the danger of sloughing of skin over the displaced body of the bone 2) the difficulty of replacing the body of the talus in the *tibio-fibular mortise* 3) *the frequent association of fracture of the medial* malleolus with interposition of periosteal tissues and 4) the danger of avascular necrosis of the dislocated body There is also danger of compression of the posterior tibial neuro vascular bundle by the displaced body of the talus, threatening gangrene of the forefoot If operative replacement is needed care must be taken to protect these vessels

Urgency of reduction—When the body of the talus lies over the inner aspect of the tuber calcanei the skin is tightly stretched over it and there is danger of sloughing from pressure on the deep surface and loss of blood supply If this occurs the bone forms a sequestrum in an infected wound *The only measure of treatment then available is from the point of view of* function the worst treatment—namely excision of the dislocated body Reduction is urgent The talus must be replaced at once whether by manipulation skeletal transfixion or even if necessary open reduction.

Reduction of dislocation—In attempting manipulative reduction the mechanism of displacement should be remembered. The foot should be put back into the position of deformity which it occupied at the moment that the body of the talus and the tuber calcanei became interlocked—that is full dorsiflexion with the heel pulled forward This itself may replace the body of the talus in the tibio fibular mortise The heel is then everted in order to unlock the sustentaculum tali. Finally the foot is plantar flexed, to reduce the subtalar dislocation while thumb pressure is maintained behind the ankle joint to prevent the body of the talus from redisplacing

Skeletal traction—If this manipulation fails traction may be used with a pin in the calcaneum and a tibia traction apparatus so that the space between the tibia and calcaneum is increased After everting the heel thumb pressure is applied over the back of the body of the talus to push it forwards into the mortise If there is still no success a second pin may be driven into the body of the talus by which to rotate it and guide it back to its socket (Figs 1426-1430) As a final resort an incision should be made over the postero-medial aspect of the joint or through the midline posteriorly splitting the tendo Achillis vertically The bones are unlocked by a lever between the sustentaculum tali and talus and the talus is pushed forwards into the joint

Fracture of the medial malleolus—There is often an avulsion fracture of the medial malleolus and when the body of the talus has been reduced there may be radiographic evidence that the malleolar fragment is not accurately replaced because a periosteal flap is interposed between it and the tibia (Fig 1436) A short incision should be made to withdraw the flap

injury to the cord, but at the same time with sensation preserved over the front of the thigh and with slight power in the flexor and adductor muscles of the hip proving survival of the first second and third lumbar nerve roots, the main endeavour of treatment must be to protect these roots because the function they serve will make all the difference between a permanent wheel chair existence and a more vigorous life of standing and walking

Fig 1567

Fracture-dislocation of the spine produced by rotational force with a "slice-fracture" of the vertebra associated with injury to the apophysial joints. Evidence that the injury was produced by rotational violence is shown in the dislocation of the twelfth rib on the left side This type of fracture-dislocation is unstable and, if there is not already injury to the spinal cord or cauda equina, such nerve injury may well arise unless immobilisation is complete, preferably by early internal fixation. (*By permission of F W Holdsworth J Bone Joint Surg* 1953, 35-B, 540.)

In this rests the justification for early internal fixation of fracture dislocations at the thoraco-lumbar junction by plates and bolts, or plate and screws in order to correct displacement prevent redisplacement and protect the nerve roots First however let it be declared as forcefully a possible that the operation of internal fixation of fracture-dislocations o the spine can never be a substitute for good nursing The first and mos essential part of the treatment of a paraplegic patient is to nurse him i such a way that no pressure sores arise no contractures occur and no urinary infection develops This is much more important than any operation o

sharing with me a lecture course in the United States said "if they have good upper limbs and are intelligent they can be assured of an ability to walk though perhaps with appliances they will gain complete twenty four hour control of the bladder and bowel and they will earn their own livings and lead an almost normal life" Surely this is an amazing reversal of attitude It is indeed But amazing as it may be it is reaffirmed in many other parts of the United States in Canada and Great Britain Unlike the sole survivor of traumatic paraplegia from the first world war, of the four thousand American soldiers paralysed from spinal injury in the second world war

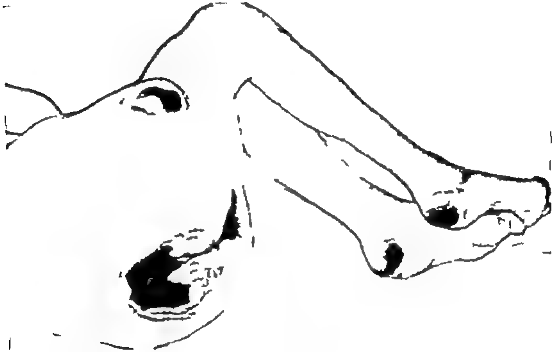


FIG 1561

This patient sustained a fracture of the spine with paraplegia and flexor spasm of the lower limbs. Severe and extensive bed sores were allowed to develop over the sacrum, both trochanteric regions and both heels. "Bed sores in the paraplegic should be looked upon as a disgrace"

more than two thousand are surviving and of these 80 per cent are able to walk and 80 per cent are in jobs or training for jobs In Toronto Botterell and his colleagues [1,2] have resettled paraplegics, many of them driving their own cars to the city and getting about not only with wheel-chairs but with such crutch walking as is needed for an active life

Remarkable results have been gained by Guttmann [3-5] at the Stoke Mandeville Hospital near London Not only has he cured neglected decubitus ulcers contractures of joints and spasm of the lower limbs in patients with traumatic paraplegia of long standing but above all he has inspired them with a new faith and new hope Only those who have visited and stayed at

Botterell, E. H., Jousse A T., Aberhart C., and Cluff J W "Paraplegia following War" *Canad med Ass. J* 1946, 55, 49
Botterell, E. H Callaghan, J C., and Jousse A. T "Pain in Paraplegia Clinical Management and Surgical Treatment. *Proc R. Soc Med.*, 1954 47 281-8
Guttmann, L. "Rehabilitation after Injury to the Spinal Cord." *Brit. J phys Med* 1946, 9, 130 162.
Guttmann, L. "Treatment of Bed Sores." British Surgical Practice Butterworth, 1948, 2, 43.
Guttmann, L. "Surgical Aspects Treatment of Traumatic Paraplegia. *J Bone Joint Surg.*, 1949 31-B, 399.

internal fixation. It is unfortunate that recent progress should have been disturbed by some surgeons who have thought that no problem of nursing would arise if operations were performed for internal fixation of the fractured spine (Figs 1579 1582)

Lumbar puncture in the investigation of spinal cord injuries—Little is to be gained by lumbar puncture because there may be temporary complete obstruction of the flow of cerebrospinal fluid in both complete and incomplete cord injuries. Furthermore even when the cord has been transected, there may be a free flow of fluid; clearly there must have been a spinal block at the moment of injury but very often displacement of the vertebræ is

FIG 1568

Fracture-dislocation at the upper lumbar level from rotational violence with locking of the articular processes. If there is not already a spinal cord or cauda equina injury there is certainly grave danger of paralysis being produced if such an injury is treated by simple hyperextension and immobilisation in plaster because the locked processes hinge on each other and cause stretching of the cord with late development of paraplegia. It is essential to perform an operative reduction, usually with facetectomy at least on one side

almost completely reduced as the patient is laid flat so that communication of fluid above and below the level of fracture is at once restored. A normal pressure of cerebrospinal fluid below the level of a vertebral fracture does not therefore exclude the possibility of serious displacement at the moment of injury

Immediate laminectomy—Formerly it was often advised that in fracture-dislocations of the spine with paraplegia an immediate laminectomy should be performed as an emergency operation not only with the object of decompressing the spine and nerve roots but also to determine by direct inspection the exact nature of the injury[1] It is now agreed that more information can be gained from clinical neurological investigation than

[1] Naffziger H C "Treatment of Fractures of the Spine with Cord Injury" *Northw Med* 1927 26, 9.

this centre for paraplegics can understand how great has been his success in restoring a spirit of confidence and self-dependence. Visitors come away humbled but inspired.

In Sheffield, Holdsworth with his team[1, 2] has proved convincingly the real answer to the whole problem—namely, the immediate admission of patients with traumatic paraplegia to a special centre within the first forty-eight hours, so that decubitus ulcers and renal infections never occur.

FIG. 1562

Specimen of fracture-dislocation of spine showing crushing of cord between the upper angle of the vertebral body below and the laminæ of the vertebra above. There is also pressure on the cord by backwardly displaced disc material. *(Specimen in the Pathological Museum of the Liverpool University Medical School.)*

The function of uninjured nerve roots is preserved, and the re-education of standing, walking, playing and working begins within a few weeks or months, long before recovery is threatened by despair and despondency.

No longer is there sedation with morphine and hyoscine; these drugs hardly exist in the dispensary. Instead there is exercise, recreation and work. From the very beginning there is inquiry as to the sort of job the patient would like to learn. There is promise of a useful and satisfying life.

Holdsworth, F. W., and Hardy, A. G. "Early Treatment of Paraplegia from Fractures of the Thoracic Lumbar Spine." *J. Bone Joint Surg.*, 1953, 35-B, 540.
Holdsworth, F. W. "Traumatic Paraplegia." *Ann. R. Coll. Surg. Engl.*, 1954, 15, [illegible]41.

RELATION OF SEGMENTS OF THE SPINAL CORD AND NERVE ROOTS TO THE VERTEBRAL BODIES AT THE THORACO-LUMBAR JUNCTION

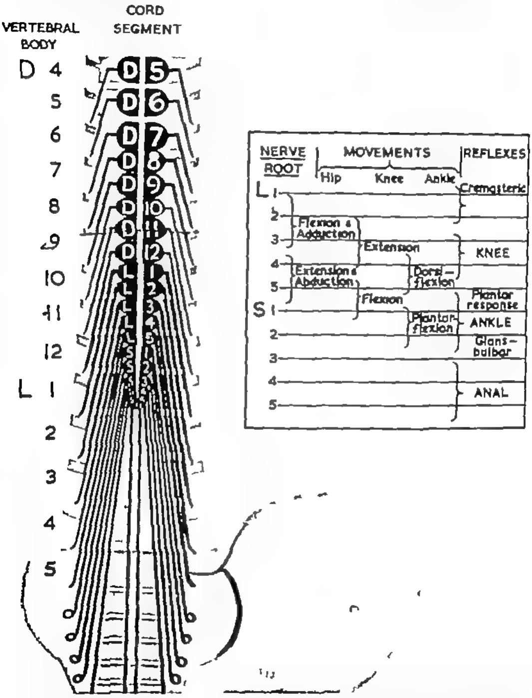


Fig 1560

This diagram shows the relationship of segments of the spinal cord and the emerging nerve roots to the vertebral bodies Note that all the lumbar segments of the spinal cord are concentrated at the level of the tenth dorsal to the first lumbar vertebræ The table shows the motor distribution of corresponding nerve roots and the reflexes associated with them.
(*By courtesy of Holdsworth F W and Hardy A, "Jour Bone and Joint Surg"* 1953, 35-B, 540.)

from inspection at the time of a laminectomy [1] Laminectomy should be undertaken only when definite indications exist in three types of cases 1) in the rare case of depressed fracture of a lamina with protrusion of bone into the spinal canal, especially at the thoraco-lumbar junction where the injury may be of nerve roots rather than of the spinal cord 2) in incomplete lesions when progressively increasing neurological signs suggest the development of an epidural hæmatoma 3) in complete or incomplete paraplegia where there is no radiographic evidence of fracture or dislocation but there is a block to the flow of spinal fluid as proved by lumbar puncture [2]

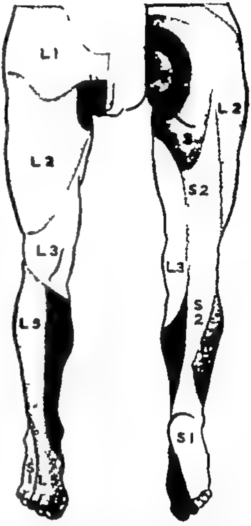


FIG 1570
Sensory distribution of the lumbo-sacral nerve roots. This should be studied in conjunction with Figure 1560

SUMMARY OF NEUROLOGICAL AND RADIOGRAPHIC INVESTIGATION OF VERTEBRAL INJURIES WITH SPINAL CORD AND NERVE ROOT INJURIES

1 *Spinal concussion* causes motor and sensory paralysis below the level of injury but the motor and sensory disturbance is nearly always incomplete and usually there are signs of recovery within a few hours

2 *Crushing of the thoracic or cervical* cord causes complete sensory motor and visceral paralysis at first overshadowed by spinal shock with suppression of reflex activity in the distal separated part of the cord so that paralysis is flaccid reflexes are suppressed, and the flaccid bladder functions only by overflow incontinence—but within a few hours reflex activity of the spinal or decerebrate animal becomes apparent in the reappearance of anal and glans-bulbar reflexes associated with motor and sensory loss beyond the level of injury Within a few days or weeks full reflex activity in the separated part of the cord is established perhaps with spasticity of muscles and a tendency to contracture and with reflex emptying of the bladder

3 *Crushing of the lumbar nerve roots of the cauda equina* in the lumbar spine causes loss of sensation and flaccid paralysis with an isolated or autonomic bladder at first with overflow incontinence and then imperfect emptying of the bladder by local myoneural reflex activity Whereas recovery is impossible after transection of the spinal cord complete recovery may occur from injury to the nerve roots of the cauda equina

[1] Kaufman H. C. "Neurological Aspects of Injury to the Spine" J Bone Joint Surg., 1938 20, 444
[2] Pennybacker J B. "The Treatment of Traumatic Paraplegia. J Bone Joint Surg 1953 35-B, 517

Mechanism of normal micturition—The bladder and its sphincters are innervated from sympathetic parasympathetic and somatic sources The motor nerves to the bladder arise from the second and third sacral segments passing through the parasympathetics to the detrusor muscle Normally there is a reciprocal arrangement between the detrusor and the internal sphincter of the bladder by which when one is contracted the other is relaxed Micturition is accomplished by contraction of the detrusor initiated by stretching of the bladder wall and associated with relaxation of the sphincter This reflex mechanism is centred at the second and third sacral segments

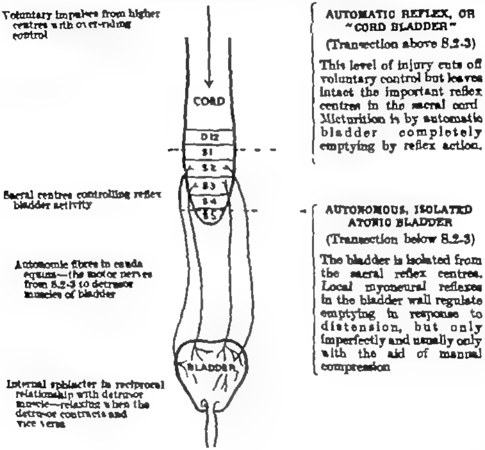


Fig 1583

Diagram to show sacral centres controlling reflex bladder activity and the distinction between the automatic reflex or "cord bladder" and the atonic, autonomous or isolated bladder

of the spinal cord but normally it is also under higher control from the voluntary impulses of cerebral centres (Fig 1583)

Mechanism of micturition after spinal injury—If the spinal cord is damaged in the thoracic region there is first retention of urine then retention with overflow incontinence and then periodic reflex micturition through the centres in the sacral cord Retention of urine usually lasts for about twenty four to forty-eight hours after which time urine dribbles away from the distended bladder with overflow incontinence The third stage of periodic reflex micturition begins at an interval varying from several weeks to several months as the detrusor muscle regains its tone and recovers its contractility in response to stretching acquiring once more the reflex of

4 *Crushing of the thoraco-lumbar cord as well as the nerve roots alongside, at the tenth thoracic and second lumbar level* is perhaps the greatest problem because it is sustained at the site where fracture-dislocations occur most frequently—at the thoraco-lumbar junction of the spine Early evidence of reflex activity is a sure indication of damage to the cord, but disparity in the level of the nerve lesion as between the radiographic and neurological study indicates escape of injury of some of the nerve roots, the function of which must be preserved because it may make the difference between a wheel-chair life and a life of reasonable walking with crutches

Injury to the cord and nerve roots at the low cervical level [1 5]—Although special emphasis has been placed on combined injuries of the spinal cord and nerve roots at the dorso-lumbar junction because this gives rise to very special problems of treatment it must of course be recognised that at the cervico-dorsal junction there may also be combined injuries of the cord and nerve roots

Injury at the fifth cervical level—If there is injury at the level of the fifth cervical segment the arms are completely paralysed, together with paralysis of the whole trunk and lower limbs Respiratory movement is then sustained only by the diaphragm supplied from the phrenic nerves emerging at a higher level all intercostal muscles being paralysed

Injury at the sixth cervical level—Injury at the sixth cervical level leaves normal power in the deltoid muscles of the shoulder and the flexor muscles of the elbow so that the patient lies with the shoulders abducted and the elbows flexed the forearms being supinated

Injury at the seventh cervical level—If there is injury to the seventh cervical or first dorsal segments there will also be paralysis of the intrinsic muscles of the hand with a main-en griffe deformity resulting

THE NURSING OF PATIENTS WITH TRAUMATIC PARAPLEGIA

We will consider the nursing of paraplegic patients first since it so greatly outweighs any other part of the treatment It is relatively unimportant whether the surgeon decides to use internal fixation of th actured spine
or to rely on conservative measures What does matter e nursing
shall be so careful that there will be no bed sores no s and no
infection of the urinary tract The patient should be n ery thick
mattress with many pillows or sorbo pads He must from on
position to another at regul urly intervals be
immobilisation in plaster jac spicas or plas almo
invariably give rise to serious s Througho wee
the patient must be moved re in such sp
is kept in the neutral posit hyperflexed n
This calls for special skill and g of team
orderlies who learn how to m with su
trunk that flexion extension a ains of

Morton, S. A. Localised Hypertrophic C he with
or of its Roots." *J Bone Joint Surg.*, 193
Barnes, R. "Paraplegia and Cervical Spin *J Bur*
Taylor A. R., and Blackwood, W "Parapl ical 1
Appearances." *J Bone Joint Surg* 1948,
Barnes, R. "Mechanism of Cord Injury wit *J*
Taylor A. R. "Mechanism of Injury to wi
Column." *J Bone Joint Surg* 1951 33-B.

emptying When the spinal-cord injury is in the thoracic region and the sacral segments are spared this is a true automatic reflex or cord bladder many afferent stimuli sufficing to initiate the reflex This is usually acquired within a few months The act is involuntary and it cannot be prevented or interrupted *Patients are often aware that the bladder is distended by* reason of such perverted sensations as vague suprapubic discomfort sweating, fluttering in the buttocks pain in the penis or in other ways These signs are important because they warn the patient of impending bladder activity sometimes for as long as five or ten minutes With good training the patient may learn to recognise these sensations and initiate reflex emptying of the bladder by applying stimuli to the skin of the groin, lower abdomen or penis. The time elapsing between each occasion of reflex emptying of the bladder may be as long as four hours unless there is urinary infection, when there may be frequency of micturition with intervals of no more than fifteen or thirty minutes

When the injury to the cord is at the sacral level or through the roots of the cauda equina periodic reflex micturition develops much more slowly—seldom in less than six months Once again, distension of the bladder is usually appreciated by the patient with a warning of impending micturition lasting as long as fifteen minutes Micturition must then be started by straining and contraction of the abdominal muscles At first the stream of urine is good and it continues as a fairly strong stream so long as straining is maintained, but it falls off as soon as the abdominal muscles are relaxed Moreover the bladder is seldom emptied completely

Methods of draining the paralysed bladder—It is evident that successful management of the paralysed bladder depends upon prompt drainage by which it is emptied completely at regular intervals allowing neither distension nor contraction of the bladder wall and always preventing infection There are three ways in which such drainage can be maintained 1) simple overflow incontinence aided by manual compression and sometimes in emergency by suprapubic aspiration 2) continuous urethral catheterisation 3) high suprapubic cystostomy with tidal drainage Intermittent catheterisation is mentioned only to be dismissed because it usually causes injury and infection of the urethra leading to secondary ascending infection [1] Perineal urethrostomy is also mentioned in passing because despite theoretical support its practical application is charged with danger—the patient lies in a puddle of urine with certainty of serious decubitus ulceration

1. Overflow incontinence and manual compression—In emergency treatment the distended bladder which is separated from all reflex control by the suppression of spinal shock, is best left alone for thirty-six to forty-eight hours It is only when the bladder is allowed to remain distended for many days or weeks that danger arises especially when there is already infection Overflow emptying may be aided by manual compression so long as it is done carefully This technique may cause ureteric reflux and even cause ascending infection of the renal tract [2] but little or no danger arises if the technique is used only in emergency situations for no more than a day or two If at this stage the bladder *must* be emptied because of acute distress from retention without as yet any overflow it can be done by

[1] Vellacott, P N and Webb Johnson, A. E. *Lancet* 1919, 1 733.
[2] Bors, E., and Comarr A. E. Vesico-ureteral Reflux in Paraplegic Patients. *J Urol.*, 1952, 68, 691.

Preventing pressure sores—A bed sore, trophic sore pressure sore decubitus ulcer, or whatever you like to call it is a disgrace—it is no less a disgrace in a patient with traumatic paraplegia than in any patient in any hospital Nevertheless none should imagine that this ideal of treatment is easy of achievement It is not enough to supply a few extra pillows or for a nurse to look at the patient two or three times each day There must be a rigid and closely guarded regime On top of a thick sorbo mattress there should be at least ten or a dozen pillows placed beneath the loin the thighs and the legs and with pillows between the thighs and legs in order to prevent pressure contact (Figs 1571 1572) The required position of slight extension of the spine with the hips extended and slightly abducted the knees extended and the ankles dorsiflexed can be maintained if the pillows are correctly placed Some may prefer to use the still more resilient pads of thick sorbo rubber (Figs 1573 1574)

No less important than correct placing of the pillows or sorbo pads is constant readjustment of the position of the patient He must be turned first to the left, then to the right then on the back and sometimes on the face regularly at two hourly intervals throughout the day and night Let this be understood quite clearly—he must be wakened at night for turning as well as being turned throughout the day Since the patient is completely insensitive and incapable of active movement pressure sores can arise within a few hours Every time that he is so turned the skin should be inspected and at the first sign of the slightest redness over any bony prominence the attention of the surgeon must be drawn to it It should also be remembered that decubitus ulceration may arise without preliminary warning in redness of the skin Continued pressure for a few hours often causes necrosis of the subcutaneous tissues the full extent of such damage not necessarily becoming obvious in the form of a superficial sore until some time after Thus regular two-hourly turning is imperative With such a regime in a consecutive series of more than one hundred patients with traumatic paraplegia treated from the beginning in a special centre Holdsworth was able to write[1] During the past seven years we have not had one single serious pressure sore in patients so treated Once a day the skin over the bony prominences in the paralysed areas is gently massaged with soap and water it is then dried with soft towels and powdered. Later on the frequency of turning may be reduced from once every two hours to once every three hours and then to once every four hours

Preventing contractures—Since the patient has lost active control of the joints of the lower limbs the range of movement of the paralysed joints must be preserved by assisted passive movement The toes should be flexed the ankles dorsiflexed the knees flexed to beyond the right angle and the hip joints extended and abducted There must never be forced or violent stretching or passive movement not only because this may cause spasm and mass reflex but also because it increases the tendency to stiffness of the joints and may even give rise to widespread ossification in the soft tissues

Supported passive movement to paralysed joints in the swimming pool—After the second or third month gently supported movements of paralysed joints may be aided by the patient s own endeavours in the swimming pool

[1] Holdsworth, F W., and Hardy A. "Early Treatment of Paraplegia from Fractures of the Thoraco-lumbar Spine J Bone Joint Surg 1953 35-B, 547

aspiration immediately above the pubis through a serum needle. Such aspiration should not, however, be undertaken more than once or twice.

2. **Indwelling urethral catheter**—A catheter of the Foley type no larger than No. 18 French gauge should be used.[1] The catheter should be introduced with every precaution of asepsis and non-touch technique. The surgeon must scrub up, wear gloves and be gowned and masked—it is to be regarded as a major surgical procedure demanding every precaution of asepsis such as is needed in any other operation. The catheter is attached to a rubber tube and the urine is allowed to flow through it into a drainage bottle beneath the bed. Twice daily the bladder is emptied by the suction of a syringe; having been cleared of debris it is then distended with half a pint or a pint of suitable antiseptic solution such as Suby's solution M, which has a pH of 5.5.[2] The catheter is changed once every week, this again being done with full aseptic precautions.

3. **High cystostomy with tidal drainage**—The advantage of continuous urethral catheterisation is that by suitable suction the bladder can be emptied completely, all residual urine being removed before it is distended twice each day. The disadvantage of an indwelling urethral catheter is that it may cause urethritis. Thus many surgeons prefer tidal drainage through a catheter introduced into the bladder through the mid line of the abdominal wall.[3-4] It is a mistake to think of this as a *suprapubic* cystostomy if that is thought to imply drainage of the bladder just above the pubis, which permits contracture of the bladder wall. The catheter should be introduced at the mid point between the umbilicus and symphysis or even higher than that if bladder dullness extends to a higher level. It is introduced by means of a steel trocar which is passed downwards and backwards making an angle of 45 degrees with the skin of the abdominal wall.[5-6] Another instrument—an advancer—is used to thrust the catheter into the bladder to any desired depth, usually about five inches. During the first two days the bladder is emptied very slowly. Then the catheter is connected to a tidal drainage apparatus. This is a simple arrangement with a reservoir for fluid connected by two Y tubes, one to the catheter in the bladder and the other to a syphon tube open at the top (Fig. 1584). Fluid is dripped from the reservoir, filling both the bladder and the syphon tube. When the fluid level reaches the top of the tube, syphonage starts and the bladder is emptied. A vent of air allows the syphon to break so that filling begins once more.

Antibiotic control of infection of the urinary tract—There is seldom need for chemotherapy. The essential control of urinary infection rests in perfect asepsis and non-touch technique in introducing catheters whether through the urethra or in drainage by suprapubic cystostomy. If, however, urethral, vesical or renal infection does arise the responsible organisms should at once be identified and suitable chemotherapy be instituted.

Training the patient in control of reflex bladder activity—After the first

Hardy, A. G. "Early Treatment of Bladder in Traumatic Paraplegia." *J. Bone Joint Surg.*, 1954, 36-B, 365.
Suby, H. I., and Albright, F. "Dissolution of Phosphatic Urinary Calculi by Retrograde Introduction of a Citrate Solution containing Magnesium." *New Engl. J. Med.*, 1943, 228, 81.
Munro, D. "Cord Bladder: Its Definition, Treatment, and Prognosis when associated with Spinal Cord Injuries." *New Engl. J. Med.*, 1936, 215, 766.
Bors, E. "Bladder Disturbances and Management of Patients with Injury to the Spinal Cord." *J. Int. Coll. Surg.*, 1954, 21, 513; 1954, 22, 61.
Riches, E. W. "Method and Results of Treatment in cases of Paralysis of the Bladder following Spinal Injury." *Brit. J. Surg.*, 1943, 31, 135.
Riches, E. W. "The Bladder in Traumatic Paraplegia." *J. Bone Joint Surg.*, 1954, 36-B, 351.

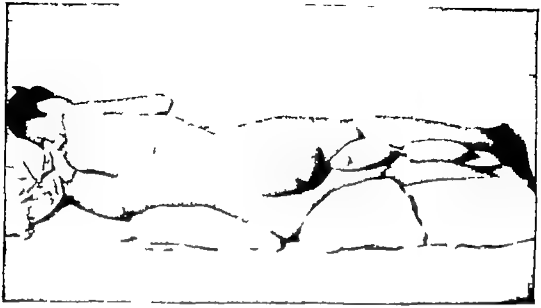


FIG 1571
Nursing of the paraplegic patient on a sorbo mattress with very many pillows.

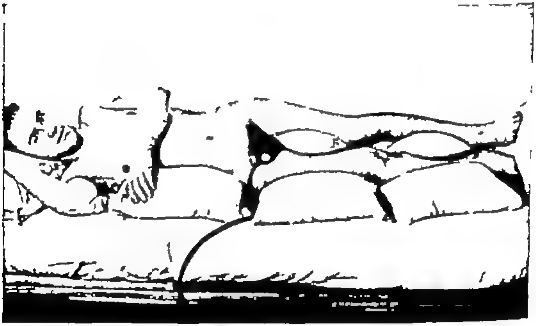


FIG 1572
The most important problem in the management of patients with traumatic paraplegia is good nursing by which to prevent contractures and avoid pressure sores. As well as a soft and very thick mattress there must be pillows so placed as to prevent pressure over the sacrum, trochanters and heels. Note also the small pillows placed between the thighs and legs. (*Photographs by courtesy of F W Holdsworth.*)

few weeks the patient should try to gain control of bladder drainage by means of a screw-clip applied to the drainage tube operated by the patient himself In this way the bladder can be allowed to fill and the patient must learn to recognise and interpret the sensations arising from a full bladder and to act upon them by deliberate emptying aided by such afferent stimuli as stroking the groins or lower abdomen together with gentle manual compression, deep breathing straining of the trunk muscles, adoption of the upright position or of any other posture which may help in completing reflex emptying When there are signs that such reflex activity is developing the catheter should be left out for trial periods of several hours If there is evidence that the patient can at least partly empty the bladder the trials should be continued over longer periods Careful watch must be kept with accurate assessment of residual urine by which to determine the efficiency of the patient's own voiding of the bladder It is reasonable to accept a residual urine of about 25 per cent of bladder capacity but if the residue is more than this the catheter should be kept in position for a longer period in order to prevent pooling of urine which promotes infection or distension of the bladder weakens the detrusor muscles and delays the establishment of reflex emptying At this stage there should be careful control of fluid intake especially late at night The optimal output of urine is about 300 c c every two hours

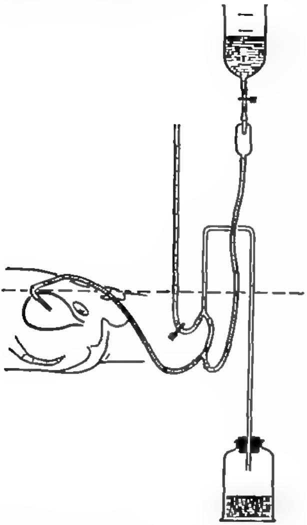


FIG 1384
Tidal drainage for the paralysed bladder used in association with a catheter introduced by high cystostomy

Management of the paralysed bowel—The function of the bowel is always disturbed and too often it is neglected Dirty beds and dirty linen are not inevitable sequelæ of traumatic paraplegia By the judicious use of aperients and enemas sometimes aided by manual evacuation accidental bowel action can be reduced to a minimum No patient should be allowed to remain constipated for more than two or three days Injections of prostigmine or pituitary extract may be useful in the early stages even after that regular enemas and aperient drugs are often required. Every effort should be made to establish regular periodic evacuation initiated by a habit reflex and aided by abdominal straining

FIG 1573
Nursing of a paraplegic patient with sorbo-rubber pads.

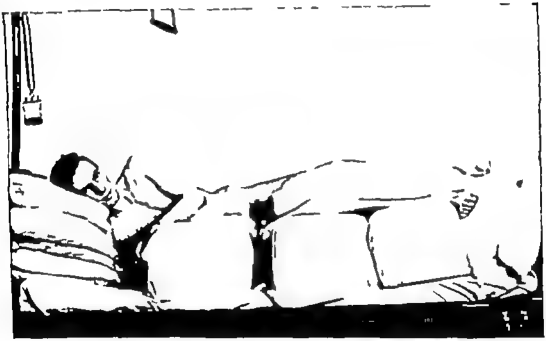


FIG 1574
In treating paraplegic patients it may be wise to support the limbs not only with many pillows of the ordinary type but to use sorbo pads such as are illustrated in the nursing of this patient. Note that the feet are supported in the right-angled position but with no pressure behind the heels, and that no pillows are placed behind the knees which would encourage flexion contracture.
(From the Stoke Mandeville Hospital by courtesy of Dr L. Guttmann and Miss Hobson.)

REDEVELOPMENT OF THE UPPER LIMB MUSCLES IN PARAPLEGIC PATIENTS

No matter whether a fracture-dislocation of the spine has been treated conservatively or by internal fixation the essential measure of after treatment is to develop the muscles of the upper limb upon which the patient will depend for further activity He must first be taught to sit in bed This may seem to be obvious, but the fact is that sitting upright in bed is one of the greatest difficulties with which a paraplegic patient is faced It may be that preservation of some lumbar nerve roots at the lumbo-dorsal junction has conserved power in one or two muscles of the hips and thighs—but in other cases when the spinal injury is at a higher level there may be only one muscle that can be relied upon to balance the trunk upon the pelvis namely the latissimus dorsi which is innervated from a higher level of the cord This may be the only muscle to be relied upon in acquiring a balance by which the patient can make a reasonable attempt in standing and walking with crutches With this muscle alone he can learn a swing through gait the two crutches first being advanced and the lower limbs being swung through like a pendulum If one or more of the hip or thigh muscles have also been preserved the patient may learn a more normal type of gait, with co-ordination of the right arm and left leg and then the left arm and right leg As the right crutch is advanced the left leg is swung forwards as the left crutch is advanced the right leg is moved and so a satisfactory gait can be learned

The patient must first sit up in bed and gain his balance (Fig 1585) He must then learn a similar balance with arms outstretched which is much more difficult because the centre of gravity is then disturbed (Fig 1586) He must learn a similar balance despite sudden and unexpected strains Such activities as throwing a ball to the physiotherapist and receiving it back from her are excellent measures in restoring the sense of balance which is so essential (Fig 1587)

The power of all the upper limb muscles should be developed by regular exercises including for example the use of an elastic chest-stretcher as well as by such games as table tennis and netball (Figs 1588-1589) Archery is of special benefit paraplegic patients become so good at it that they have won many international competitions against able bodied opposition This and other games redevelop the shoulder girdle muscles (Figs 1590 1591) Throwing the javelin is another recreational activity which combines diversional interest with development of the muscles of the upper limbs upon which so much is dependent

The fitting of light aluminium splints by which to hold the ankles in right angled dorsiflexion and the knees straight is usually needed The patient is first taught to stand with the support of parallel bars (Figs 1593-1594) When he has gained confidence he is taught a simple swing through movement of the lower limbs while still supporting himself on the bars by means of the upper limbs Then if muscle power suffices he is taught a three point gait with right arm left leg and left arm right leg co-ordination (Figs 1595-1598) There must be careful graduation from the full support of parallel bars to the relative perils of crutches with the support of a physiotherapist From

Even when there is paralysis at a high thoracic level the patients can swim in a warm bath the paralysed limbs moving passively with the support of the water while the power of the upper limbs is developed by the efforts of the patient

INTERNAL FIXATION OF THE FRACTURED SPINE WITH PARAPLEGIA

Many surgeons believe that a sufficient degree of protection of fracture-dislocations of the spine can be secured by correct positioning in bed with pillows On the other hand if it is done skilfully internal fixation with plates and bolts facilitates the problem of nursing and the regular

Fig 1575

Fig 1576

Fracture-dislocation of the spine with gross forward displacement of the twelfth dorsal on the first lumbar vertebra (Fig 1575) This has been treated by the internal fixation of double plates and bolts after reduction of the displacement (Fig 1576) (*Operation by F W Holdsworth.*)

movement that is required It must be understood, however that such fixation is no more than an aid to good nursing Plating of a fractured spine must never be regarded as an alternative to good nursing Unfortunately this obvious principle has not always been recognised Figures 1579-1582 show a horrible example

Fifteen years ago I used internal fixation with plates and screws for traumatic paraplegia in pilots of the Royal Air Force whose spines had been fractured Since then Holdsworth has developed the technique with great success in the treatment of miners suffering traumatic paraplegia [1,2] It is of course true that metallic internal fixation cannot long maintain its support in bone when external stresses are applied Nonetheless in spinal

Holdsworth, F W and Hardy, A "Early Treatment of Paraplegia from Fractures of the Thoracic Spine *J Bone Joint Surg* 1953, 35-B, 540
Holdsworth, F W "Traumatic Paraplegia." *Ann. R Coll. Surg. Engl* 1954 15, 281

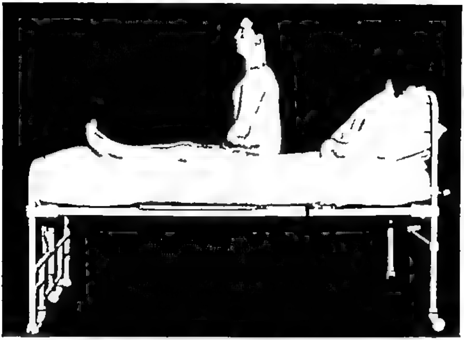


FIG 1585
Teaching the paraplegic patient to sit upright. This is more difficult than it may seem

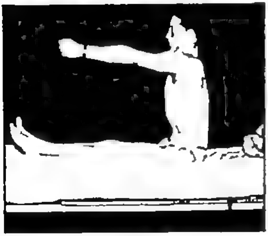


FIG 1586

FIG 1587

In traumatic paraplegia balance may depend solely on the trunk muscles innervated from a level higher than the fracture In dorsal fractures the latissimus dorsi is often the only muscle which can stabilise the trunk and allow the patient to sit, stand and later to walk. The first and most important treatment is to teach the patient to sit (Fig 1585), then to sit with arms outstretched (Fig 1586) and then to acquire balance despite sudden strains for which such exercise as throwing a ball to the physiotherapist, and then catching it back, is excellent (Fig 1587).

FIG. 1577

Fracture-dislocation of the thoraco-lumbar spine with paraplegia.

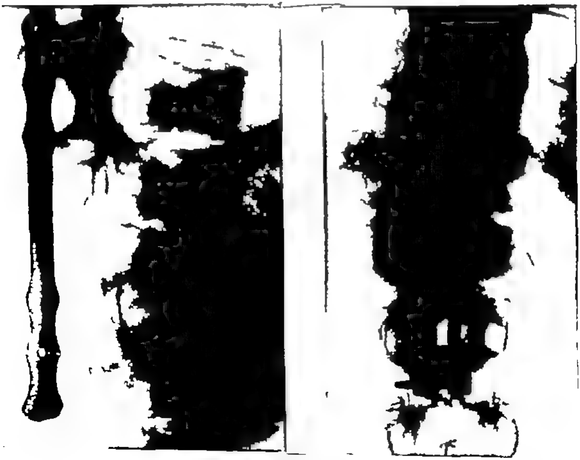


FIG. 1578

The displacement has been corrected and internal fixation secured by two plates bolted to the spinous processes. (*Operation by F. W. Holdsworth.*)

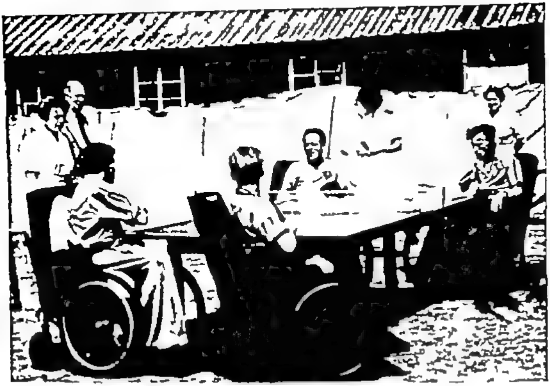


FIG 1588

As soon as the patient is up and about in a wheel-chair he should engage in diversional activities such as table tennis. The wheel-chairs are very heavily padded with sorbo-rubber

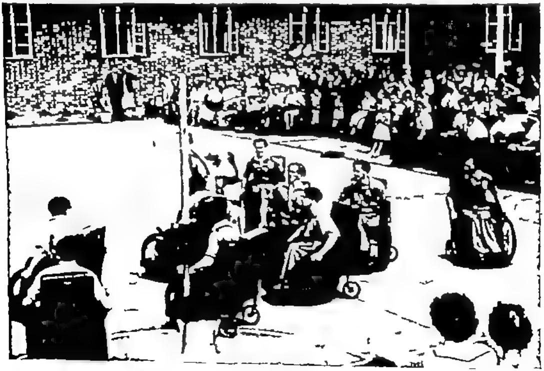


FIG 1589

Such recreational activities as netball can be enjoyed happily by patients in their wheel-chairs.
(Photographs by courtesy of Dr Guttmann and Miss Hobson, of Stoke Mandeville.)

FIG 1579

Fracture-dislocation of the spine without serious displacement treated by the application of two plates and bolts—but they were put at the wrong level so that they did not in fact protect the fracture-dislocation. (See Figures 1580-1582.)

FIG 1580

At the time of this first mistaken operation there was already an extensive pressure sore over the sacrum. The operation wound at the thoraco-lumbar junction broke down and there was serious infection.

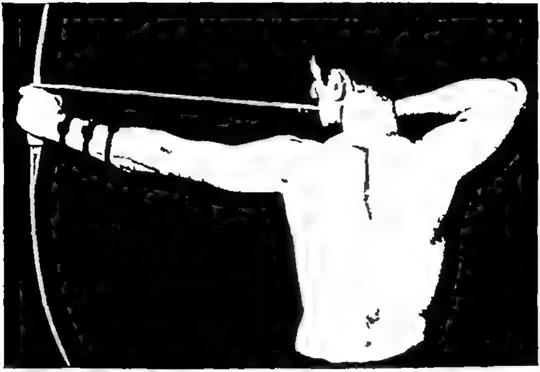


FIG 1590

Archery is one of the best actitivies for the paraplegic patient because it is much more than a diversion—it provides a powerful stimulus to development of the shoulder girdle muscles upon which the patient is going to depend

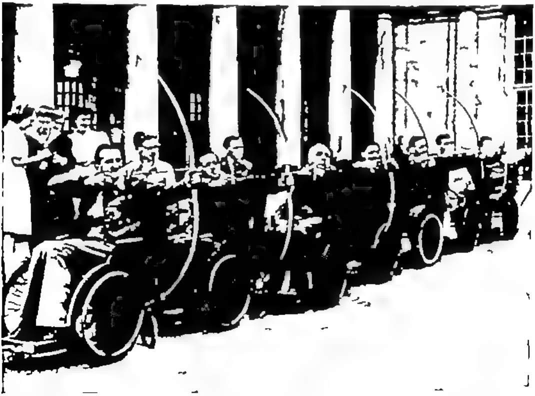


FIG 1591

This is the archery team at the Stoke Mandeville Hospital which has won so many trophies in competition with able-bodied people

FIG 1581

Despite the danger which might have seemed to be *obvious*, yet another *operation* was then done with a second pair of plates and bolts at a higher level, fixed to the lower plates by means of a miserable bit of wire

FIG 1582

This is a photograph of the wound a week or two later Let it be emphasized that in the treatment of spinal fractures with paraplegia the first and *foremost principle* is that of good nursing—not that of metallic internal fixation.

the beginning the nurse or physiotherapist must ask herself "Am I holding him or is he holding me?" At first she holds him—then he supports himself on her—and finally he walks alone. In the early days of such re-education the patient must give the whole concentration of his mind to it. Then, little by little the physiotherapist should distract him in conversation while his endeavours are made until the pattern of the movement develops without conscious effort.

Treatment of spastic contractions and mass-reflexes—In some patients with paraplegia from injury at the dorsal level, the reflex activity in the distal separated part of the cord is so vigorous that involuntary spasms and

FIG. 1592

Throwing the javelin is another recreational activity which is of value in developing the upper limb muscles.

mass-reflexes of the lower limbs make it difficult to fit appliances. It is of course much easier to teach a paralysed patient to walk if the paralysis is flaccid than if it is spastic. Sometimes the spasms are so great that operative intervention is needed. As a rule this spasticity can be relieved by such simple measures as tenotomy or lengthening of the tendo-calcaneus, division of the hamstring tendons or tenotomy of the adductors of the thighs. Occasionally peripheral neurectomy may be needed—for example division of the obturator nerves to prevent adductor spasm. Very occasionally these peripheral operations are not good enough and it may be wise to convert a spastic into a flaccid paralysis by the injection of alcohol into the theca. It may be still better to perform anterior rhizotomy which can be controlled with even greater certainty. The anterior roots from the tenth

fracture-dislocations the support of such plates can be maintained just long enough to tide over the difficult time of the first six or eight weeks. After that even without the protection of plates there is a sufficient fixation by at least fibrous ankylosis of the fractured vertebræ (Figs 1575 1578)

Technique of internal fixation of the spine in traumatic paraplegia—Four special pieces of equipment are needed (1) an operating table which can be broken in the middle into a V so that the spine may be extended at the appropriate moment (2) Egger's slotted plates—if ordinary holed plates are used it may be impossible so to place them that four holes lie opposite the spinous processes (3) Wilson nuts and bolts or some similar type (4) a pair of spanners for tightening the nuts The patient lies prone on the operating table with the fracture-dislocation of the spine level with the break in the table A mid line incision is made centred at the level of fracture-dislocation which can usually be determined accurately by feeling the wide gap between the spinous processes Sometimes there is immediate evidence of very extensive tearing of soft tissues including the fasciæ, erector spinæ muscles and ligaments As a rule however the posterior spinal muscles should be cleared and the facet articulations at the level of fracture-dislocation exposed before any attempt is made to reduce the displacement by extending the spine For example it may be found that the facets are poised tip to tip or are actually over riding the upper facet lying in front of the lower In such cases the upper margin of the lower facet should be removed by nibbling bone forceps so that the facets can be disengaged and will slide back into position as the table is racked up and the spine is gently extended Two Egger plates are placed in position one on each side of the spinous processes It is desirable whenever possible to drive bolts through two spinous processes above and two below the level of fracture Holes in the processes may be made with an angled bone awl The Wilson bolts are then put in position and the nuts are tightened.

MANAGEMENT OF THE PARALYSED BLADDER

It was estimated by Thomson Walker in 1917 that in traumatic paraplegia the death rate from urinary infection was not less than 80 per cent [1] Even to-day it is not always possible to ensure complete protection from infection of the bladder and kidneys but certainly we have progressed to the stage where such infection is relatively unimportant The objects of treatment in the management of a paralysed bladder must be (1) to prevent infection of the bladder and renal tract (2) to prevent pooling of residual urine in the bladder which would encourage infection (3) to prevent the formation of vesical calculi which is promoted when there is residual urine as well as infection (4) to prevent over-distension of the bladder because this paralyses the detrusor muscles and thus prevents establishment of reflex emptying (5) to prevent contraction of the bladder because then there can be no sufficient reservoir permitting micturition only at three-hourly or four hourly intervals Over riding all these objects we must of course recognise the ultimate aim which is despite spinal paralysis to restore periodic reflex micturition partly or wholly controllable by the patient

[1] Walker J W Thomson. "The Bladder in Injuries of the Spinal Cord." *Lancet*, 1917 1 173.

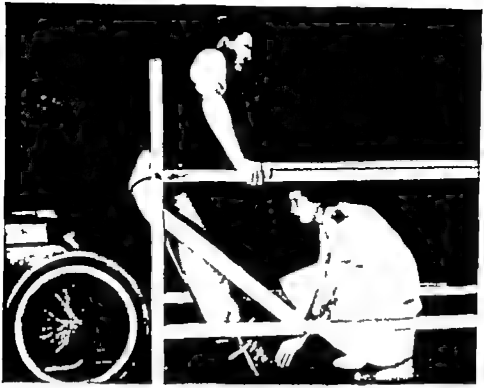


FIG. 1503
First endeavour of a paraplegic patient to stand

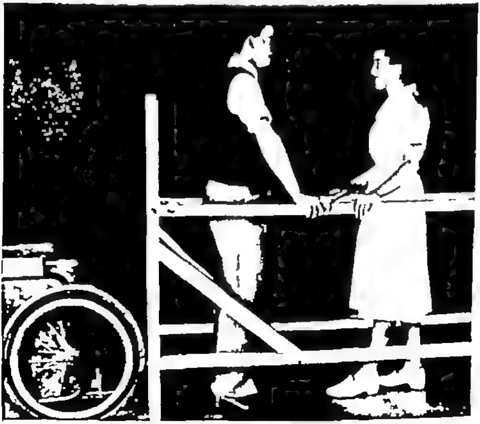


FIG. 1504
The first attempt at standing or walking should be done between parallel bars with the aid of a physiotherapist The patient must learn to stand upright then he must learn to walk with a swing through gait—perhaps finally with a three-point gait, one limb being swung at a time with the aid of crutches.

FIG 1595

FIG 1596

This patient is learning the "swing through" gait. She is suitably balanced to control the position of the lower limbs. Both crutches are put forward, and then the lower trunk and both lower limbs are swung through like a pendulum

FIG 1597

FIG 1598

She is now putting one foot forward at a time and is being taught left arm right leg and right-arm left leg co-ordination. (*Photographs by courtesy of Miss Hobson physiotherapist at Stoke Mandeville Hospital, who gained important award for her valuable work*)

with every ounce of effort ; The surgeon urges commands beseeches and demonstrates with an increasing clench of his fist until the knuckles show white through the skin , and after ten, fifteen or twenty seconds of sustained effort the muscles are relaxed and the patient sighs with relief This is resisted exercise It can be applied to the biceps, deltoid forearm or any other group of muscles It is the method which was employed by Sandow, the world s strong man ' It is used by many muscle experts of professional status who have uncanny skill in contracting any muscle independently of all others They can contract the left or the right rectus abdominis, the serratus magnus or the trapezius , and after demonstrating for five minutes though having lifted no weight and moved no joint there may be beads of

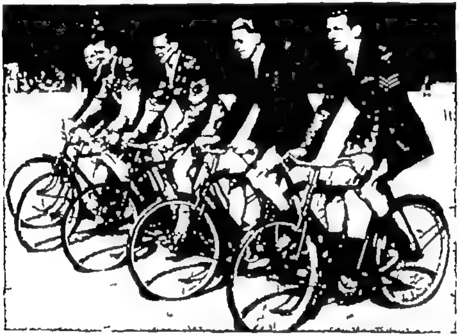


Fig 1003

Half a dozen ordinary cycles are worth many rows of fixed bicycles in a gymnasium

sweat on their foreheads ; Their muscles are superbly developed having used no other technique ; Clearly it is a mistake to believe that a pulley and weight is the only form of resisted exercise

Pulley and weight exercises—The pulley and weight system has the merits of easy localisation of exercise to one group of muscles and easy graduation of progressive resistance The weight may be increased by half pounds often without the knowledge of the patient It is of course important to control the progression carefully Sudden increase in the load has precisely the opposite effect of gradual increase the muscles of a limb react as the muscles of a hollow viscous do—they hypertrophy with stricture and dilate with stenosis Pulley weight treatment has also the advantage of developing the greatest effort as well as endurance the first is achieved by lifting a heavy weight for a short period and the second by lifting half the weight for a much longer period It is of especial value in the final stages of treatment of fractures of the spine especially when the

dorsal to the first sacral levels are divided intraspinally It is of course important not to divide the second sacral root which controls the reflex function of the bladder Before any nerve root is divided the second sacral nerve should be identified by stimulating it electrically and observing the bladder pressure as recorded by a manometer attached to a urethral catheter, when the second sacral root has been identified the four anterior roots above this level may be resected

FINAL RESETTLEMENT OF THE PARAPLEGIC PATIENT

We have discussed the treatment of patients with spinal paraplegia from the first stages of emergency and the early days when decubitus ulceration and renal infection were prevented, to the later stages when reasonable visceral control was regained with restoration of mobility by the use of properly padded wheel-chairs often teaching the patient to stand and walk. It might be thought that after that begins the final endeavour of resettlement by which the victim of injury learns a trade or job through which final independence will be secured But this is not the final endeavour—it should have been one of the first endeavours From the day that the patient was admitted to a special paraplegic unit inquiries should have been made as to his interests and intellectual capacities During the several months of physical treatment he should have discovered his ultimate aim—he should have known it from the beginning He may possibly have learned shorthand and typewriting or read bank management or commerce or learned languages. The resettlement of the paraplegic in his final life of independence coupled with a considerable measure of happiness starts on the day that he is admitted to a special centre with paralysis from spinal injury

patient is a heavy industrial worker (see Chapter XXXIII) But caution is necessary There may sometimes be a tendency to think that rehabilitation means no more than a pulley and weight—and nothing could be further from the truth This is but one of many types of exercise and to concentrate on any activity for hours on end is harmful through boredom There are other dangers If the method is employed at too early a stage of treatment recovery is delayed by joint reaction and pain In many hospital wards pulley systems were erected for treatment after cartilage operations but they were rapidly discarded when it was found that synovitis and effusion were aggravated Even in the later stages of treatment of cartilage cases the pulley and weight system may be unsatisfactory In most rehabilitation centres the use of this apparatus has been greatly reduced. Malkin and Parker write We have now discarded the routine use of pulley exercises in meniscotomy cases and as yet have had no reason to regret this step [1]

Free movement and recreational exercises—A patient should not sit and focus his attention on the muscles of an injured region for more than a limited time Such intervals must alternate with periods of general exercise gymnastics swimming cycling and recreation Recreations and games should be organised and related to the requirements of the individual. They should be graduated The patient may begin with standing tennis or bowls and progress through croquet or approach putting and soft-ball or hand ball to fives or squash racquets A swimming pool is invaluable particularly for derangements of the knee joint which call for non weight bearing exercise After arthroplasty of the knee joint a patient can mobilise and stabilise the surgically constructed joint by swimming, long before he is fit for gymnastic activities Cycling is another non weight-bearing exercise of value in knee-joint cases but it is to be emphasised that half a dozen cycles that can be ridden through the country are worth scores of fixed bicycles in a gymnasium Moreover fixed bicycles with adjustable resistance share all the dangers of pulley exercise

Occupational therapy—Occupational therapy of the arts-and crafts type finds its greatest application in hospital wards where there are many idle hours to fill In these circumstances both men and women find fascination in needlework and petit point But in the later stages of treatment an occupational therapy bench like a massage cubicle or remedial workshop, is no more significant than a medicine ball, climbing rope or set of skittles It is an item of equipment useful but not indispensable It is one further means of introducing variety into the necessary range of exercise A patient with stiffness of the upper limb joints may be taught to make wicker work baskets trays and stools or to work a loom The equipment of carpentry with tool handles of varying dimension is invaluable when the fingers are stiff With lower limb patients treadle machines or foot fret-saws may be used Patients with spinal injuries should fell trees saw wood and load logs on miniature conveyer belts

Massage and electrotherapy— He must cure himself—that is the doctrine of physiotherapy The greatest danger in the use of massage and electrotherapy is that the patient will lie on a couch and wait to be cured. Faradic stimulation of a muscle is no more than a feeble imitation of the

[1] Malkin, S A. S., and Parker G. "Rehabilitation in an E.M.S Orthopædic Unit." *Brit. med. J.*, 1943, 1, 315.

CHAPTER XXXV

PRINCIPLES OF REHABILITATION AFTER FRACTURES AND JOINT INJURIES

A patient was admitted to hospital for the treatment of a displaced semilunar cartilage [1] Twelve months later he was still in hospital Treatment had been continued for a long time but the incapacity was still total Why was recovery so long delayed ? What complication had arisen ? The diagnosis was correct and a torn cartilage had been removed The operation had been performed skilfully and the wound was healed soundly The ligaments were undamaged there was no synovial effusion and no arthritis It is true that the muscles were weak, and despite daily massage and two manipulations the joint was stiff The gait was slow and hesitant He could not run he had never tried to run The house surgeon blamed him for lack of co-operation and said that he was depressed disinterested, resentful and a poor type It seemed odd that he should be a poor type because he was an air-gunner—a volunteer for air-crew duties He was certainly depressed but not without good reason for after ten months the disability was more complete than on the day of admission He was disinterested because nobody takes any notice and it looks as if it is hopeless He was resentful because he could not believe that the fault was his Had he not been told that the nerve to his knee was cut ?

He was transferred to an orthopædic rehabilitation centre He saw the sky the sea the open spaces For months he had seen stone walls—the stone walls of hospital buildings the stone walls of massage departments the stone walls of many corridors Now the wind blew on his face and he felt the spring of the turf He no longer slept in a ward but in a bedroom There were no nurses He could smell no drugs or anæsthetics The rooms were brightly decorated and there were flowers The menu was varied There was an atmosphere of well being and contentment The medical officer who examined him spoke of adhesions and muscle control explained symptoms that worried him and inquired about his home and family It seemed unusual but he appreciated it He was taught exercises and put with a group of men who were boisterous and happy he sensed their optimism and was reassured He was taught to walk without a limp and was congratulated He smiled When he was idle he was told firmly that he must work. He learned to mark time on tiptoe to do it more quickly to move one inch with each step and before understanding what had happened he found he was running He had not run for nearly a year He played a game of handball and enjoyed it He became an enthusiast There was a sparkle in his eye He worked in the gymnasium played on the fields swam in the pool cycled on the track attended lectures went to concerts Time

[1] Watson-Jones, R. Rehabilitation in the Royal Air Force An Address to the Council for the Development of Orthopædics in Northern Ireland delivered in Queen University Belfast, September 1941, and reprinted *Brit. med J* 1942, 1 401.

FIG 1604

Occupational therapy

Patients under treatment at the Mansfield Rehabilitation Centre for Miners.

(By courtesy of Mr E. A. Nicoll.)

FIG 1390

Recreational therapy

Patients with fractured spines, arms and legs show concentration and determination in their faces but not a trace of depression Every patient is happy Physical and psychological treatment is indivisible

patient is a heavy industrial worker (see Chapter XXXIII) But caution is necessary There may sometimes be a tendency to think that rehabilitation means no more than a pulley and weight—and nothing could be further from the truth This is but one of many types of exercise and to concentrate on any activity for hours on end is harmful through boredom There are other dangers If the method is employed at too early a stage of treatment recovery is delayed by joint reaction and pain. In many hospital wards pulley systems were erected for treatment after cartilage operations but they were rapidly discarded when it was found that synovitis and effusion were aggravated Even in the later stages of treatment of cartilage cases the pulley and weight system may be unsatisfactory In most rehabilitation centres the use of this apparatus has been greatly reduced. Malkin and Parker write We have now discarded the routine use of pulley exercises in meniscotomy cases and as yet have had no reason to regret this step [1]

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[1] Malkin, S. A. S., and Parker G. Rehabilitation in an E.M.S. Orthopædic Unit." *Brit med. J.*, 1943, 1 314.

raced past because he was busy He became bronzed and fit He laughed and was full of the joy of life In seven weeks he returned to his work The "nerve to his knee" was forgotten

Ten months—total disability, seven weeks—full recovery that is the story of rehabilitation in one air gunner What was it that turned failure into success? Was it open air and recreation? Was it muscle redevelopment? Was it the treatment of adhesions and relief of pain? Plato knew the answer two thousand years ago[1] "*This is the greatest error in the treatment of sickness that there are physicians for the body and physicians for the soul and yet the two are one and indivisible.*" Physical and psychological treatment is indivisible Physical treatment must, of course be completed It is not enough to treat a torn ligament or fractured bone and expect the patient in his ignorance to treat a weak muscle or stiff joint The patient has no knowledge by which to distinguish the pain of adhesions calling for exercise from the pain of arthritis which calls for rest he cannot be expected to complete his own treatment The same skill and care that is devoted to the union of fractures must be applied to the development of muscles and the mobilisation of joints Exercises must be graduated they must be progressive The patient must be taught to walk climb stairs run and jump But physical exercise alone is not rehabilitation The patient must understand his disability, he must regain confidence and be inspired his doubts must not become anxieties, his fears and misgivings must be dispelled his social problems must be solved he must be reassured he must not fear the future It is the duty of the surgeon to treat both body and mind In former days physical treatment was half completed psychological treatment was wholly neglected and when a patient drew the apparently obvious conclusion that there was a residual and permanent disability and turned to the only refuge he knew—the refuge of litigation and lump-sum settlement—we blamed him and called him a malingerer Was there ever greater injustice? Malingerers are made not born Functional disorder is a complication of fracture treatment which is no less under the control of the surgeon than mal union and non union In the words of John Buchan "It is not enough to have specialists for physical diseases and specialists for psychological diseases the *same man* must in a sense be both A good doctor should be and indeed always has been something of a psychologist Every consultation and examination every preparation for manipulation or operation every interview with the patient or his relatives is an opportunity for the practice of this art Special facilities and elaborate apparatus are not essential With the right attitude of mind a surgeon can practise rehabilitation in a barn without it he will fail in the most lavishly equipped gymnasium

PSYCHOLOGICAL TREATMENT

"Medical practitioners must be alive to the psychological as well as the physical dangers of a patient who has been in an accident they must take as much care to prevent infection of his mind with insidious, morbid ideas as they do to prevent infection of his body with pathological organisms"[2]

Watson Jones R. "Surgery and Rehabilitation of Bone and Joint Injuries." John Burns Lecture delivered before the Glasgow Faculty January 1943 and abstracted *Lancet* 1943, 1 172.

Farquhar Buzzard. Evidence before the Inter-departmental Committee on the Rehabilitation of Persons Injured by Accident. H.M Stationery Office 1939

FIG 1004

Occupational therapy

Patients under treatment at the Mansfield Rehabilitation Centre for Miners.

(*By courtesy of Mr E A. Nicoll.*)

Explaining to the patient—The interpretation of diagnosis conveyed to the patient is an essential part of treatment [1] Unfortunately there is no part of treatment in which serious mistakes are more often made and no mistakes are more difficult to correct The aim should be to tell the truth, or at least *as much of it as will promote comfort and hope* With few exceptions it is the patient s right to know the truth, and it is the surgeon s duty to explain it He must explain it in simple words If he wishes to describe adhesions he should speak of glue and demonstrate the capsular plications of a joint by pleating his trousers in front of the knee thus conveying a visual impression of the purpose of flexion exercise Technical language should be avoided It is only the second year medical student who delights in the use of obscure terms and long words the surgeon must not employ them in his conversation with a patient Some time ago a patient said to me I am suffering from spondylose heredito-traumatique Isn t it terrible ? She had written it on a piece of paper so that she would not forget Eight years had passed since she sustained a minor strain of an osteoporotic spine The surgeon should have explained that her joints were not as young as they were and that her bones were not as hard so that the pain of a simple sprain might last for several weeks instead he glorified himself at her expense The psychological reflection of her pain became even worse than the pain itself. The functional complications were profound and the unfortunate woman still believed that it is impossible for her to sit in a chair For eight years she had either stood or lain on a bed

Confidence of the patient in the surgeon—The truth must be spoken not only with simplicity but with conviction There should be no hesitation and uncertainty, for the patient must believe and have faith But if a patient is to have confidence in the surgeon the surgeon must have confidence in himself he must be a master of his subject It is lack of knowledge and the desire to cover himself that allow a doctor to say No nothing much just go slow or to give the most dangerous of all advice Don t do too much All vague pronouncements leave the patient with an uncomfortable sense of doubt and even silence may be harmful when it seems to confirm an unspoken fear The world is full of friends and acquaintances fascinated by a morbid interest in the disasters of surgery who will recount every true or imagined detail of calamitous cases they remember thus turning fear and doubt to certainty

The danger of frightening the patient—The patient must never be frightened It is a grave psychological blunder to draw an exaggerated picture of the pain and discomfort of treatment in order that in the event it shall not seem too bad The mental pain of apprehension is worse than physical pain It is infamous to magnify the gravity of disability in order to emphasise the skill of the surgeon who cures it A patient who has fractured his spine must never be told that he was within an inch of his life If it is true such an observation is stupid and harmful if untrue it is dishonest and contemptible A patient with degenerative joint changes caused or aggravated by injury must not be told that he has arthritis without at the same time affirming that it is not rheumatoid arthritis In the mind of the patient arthritis causes crippling total incapacity and a bed ridden life

[1] Cole Leslie Diagnosis and the Patient *Lancet* 1943, 1 163. An admirable article which should be read by every medical student on qualification and by every practitioner and consultant, whether physician or surgeon.

patient's own contraction, and it hinders rather than helps the central co-ordination which must underlie muscle effort The faradic coil has therefore little or no part to play in rehabilitation after injury On the other hand massage radiant heat diathermy and paraffin wax baths increase the blood flow and relieve spasm and pain They are valuable preliminaries to active exercise But to prepare a limb for exercise and then neglect the exercise is misguided treatment Massage is not an end in itself it is a means to the end of activity The massage cubicle should open straight out of the gymnasium and be accepted as part of an ancillary service The masseuse should spend at least as much time in the gym as she does in the cubicle On the wall of every massage cubicle should be inscribed the words We cannot cure you. But we can show you how to cure yourself

TEACHING TO WALK, RUN AND JUMP

It must not be assumed that a patient will learn to walk, run and jump unaided If instruction is neglected disability is often prolonged But before teaching a patient to walk the surgeon must be sure that he is ready for walking No advantage is gained by driving a man to his feet with unhealed ligaments and un united fractures which cause pain and a halting gait It is better to rely on non weight-bearing exercise until healing is more advanced In early days nearly every patient limps in the same manner *If the left ankle has been fractured he puts the left limb forward cautiously* and then hurriedly brings the right foot to the same level the left is again advanced and the right brought up to it the right foot never steps in front of the left At the same time he stoops forward at the hip joint closely examining the ground over which he will tread. He also leans to the right taking weight on a stick. If such a gait is left uncorrected it soon becomes established as a habit Many patients walk with a typical limp months or even years after fracture The habit must not become established it must be corrected from the first day

Teaching to walk—A pair of crutches or two sticks may be used for a short period but one stick should seldom be used A single stick promotes a lurching gait and establishes a habit limp that is difficult to break. The patient must not even graduate from two sticks through one stick, to none He needs either two sticks or no stick at all Three points must be impressed upon him 1) equal length of step 2) equal timing 3) upright posture He should start with short steps—not more than a few inches at a time He must not be allowed to take so long a stride with the injured limb that the other cannot be brought safely in front The right foot must be put as much in front of the left as the left is in front of the right He is then taught equal timing He walks slowly at first and then more quickly the medical officer intoning with each step one—two—one—two—left—right —left—right " Finally he must stand upright He should fix his gaze on an upright line such as a door frame thus adding visual to cerebellar control of balance If there is still a momentary stoop with each step of the injured limb the surgeon should walk alongside with one hand in front of his shoulder and the other behind his buttock applying light pressure at the right moment and emphasising with each step the correction which is needed In this way it is possible to teach a patient to walk normally

There may be other fears which the patient is unwilling to disclose and which are dispelled only after careful and judicious inquiry.

The fear of industrial workers.—The particular fears in the mind of the injured workman are pain and disability, poverty and debt, unemployment and industrial downgrading, and loss of the right to compensation. It is the primary task of the surgeon to dispel the fear of pain and physical disability, but it is also his duty, through an organised social service, to remove every source of hardship and distress which may interfere with recovery. Social service is a vital aspect of rehabilitation.

TREATMENT BY SOCIAL SERVICE

It is no use teaching a man to make mats and twist raffia when his children are starving and his wife is in debt; as a form of diversional therapy it will fail. The most powerful diversion is freedom from fear and freedom from want.[1] At the very earliest stage of treatment the patient should be encouraged by solution of his social problems. Almoners must resume their proper function of investigating the social problems that may exist in the patient's home or in his place of work, and solving them for him. They must gain the confidence and respect of the patient, visit his home, solve the domestic burdens of his family and arrange for holiday convalescence. They must make contact with industrial firms in the area, with the employment exchange, and particularly with the former employer. It is often possible to arrange for graduated duties, or to secure more favourable working conditions for the man who is unfit for full work. If disability is more severe they must arrange for vocational retraining. Many trivial matters arise. The patient must be encouraged to be frank in stating his views, his fears and his grievances. The almoner must watch his interests, keep him in touch with employer and trade union, and serve as a liaison between hospital surgeon, general practitioner and industrial medical officer. Study and understanding of the personality of the patient and of his social circumstances should be the duty of every doctor who treats a patient.[2]

Very striking progress in this direction was made by my good friend Miller of Glasgow, who for many years organised a rehabilitation centre *for miners*.[3] In a small industrial clinic he treated over 2,000 patients whose fractures were united, who had been incapacitated for months or years and yet were to be described as "broken men." Simple exercises and physiotherapy were employed, but the most important treatment was social service. He refused to give medical reports, to be a witness in court, or to take any action that would imperil his authority as an unbiased adviser and confidant—but he would suggest that this proposed settlement was just whereas that was not; he would recommend that a patient was unfit for the mines, or that resumption of work was in his interest; he would make contact with the employer and see that suitable duties were found.

[1] **The four freedoms.**—"In future days we will look forward to the four essential human freedoms—freedom of speech and expression everywhere, the freedom of each person and the right to worship God in their own way everywhere, freedom from want, and freedom from fear."—*President Roosevelt, Congress, January 6, 1941.* **The Atlantic Charter.**—"Sixth, after the final destruction of Nazi tyranny, we hope to see established a peace which will afford to all nations the *means of dwelling in safety within* their own boundaries, and which will afford assurance that all the men in all the lands may live out their lives in freedom from fear and want."—Franklin D. Roosevelt, Winston Churchill. Placentia Bay, August 12, 1941.

[2] Cairns, Hugh. "Planning for the Treatment of Head Injuries." *Brit. med. J.*, 1943, 1, 312.

[3] Miller, A. Lat. Rehabilitation of the Injured. *Brit. med. J.*, 1942, 2, 209.

FIG 1605

Teaching to walk, run, jump and mount stairs

It must not be assumed that ability to run, climb stairs and jump will develop unaided; patients must be taught. Limp is corrected by analysing gait into its component movements and magnifying them. The patient is taught to go up and down stairs on a very simple wooden frame of steps with side-bars. He is taught to jump, first from low heights and then from considerable heights

he would stand no nonsense from the lead swinger and even in years of industrial depression he succeeded in re-establishing in industry no fewer than 70 to 78 per cent of patients who had been threatened with permanent and often total incapacity This was treatment of a high order A scalpel was seldom used but disability was relieved It was medicine of the body and the soul.

MUSCLE REDEVELOPMENT AND JOINT MOBILISATION

Recovery of function depends ultimately on the muscles Muscle power is the key to success [1] After considering the psychological and social aspects of rehabilitation the next most important phase is muscle redevelopment and joint mobilisation In former years treatment was concentrated mainly on movement—the range of movement was the criterion of success Stiff joints were massaged stretched and manipulated manipulations were performed under anæsthesia they were repeated at frequent intervals It was shown in the first volume that these measures *often defeat their own object and fail to increase the range* But it must also be recognised that movement is useful only when it is under muscle control A stiff joint with powerful muscles is less disabling than a mobile joint with powerless muscles The function of a muscle is not only to move a joint but to protect it If muscle control is lacking the joint is susceptible to strain—it gives way ligaments are stretched synovial folds are nipped there is recurring effusion and traumatic arthritis For this reason a patient who attempts heavy work with free mobility of the knee joint but wasting of the thigh muscles often develops a swollen joint He fails to regain strength despite active use A man may be capable of heavy work with only one-third of the normal range of elbow movement whereas another with twice that range but with less muscle power is unable to work. The first object of treatment therefore is to regain muscle control The second object is to increase the range of movement within the limits of muscle control Active exercise is the keynote of treatment whereas manipulation under anæsthesia has almost disappeared

Measuring muscle strength—In order to estimate progress and control treatment muscle strength should be measured A simple pulley system is arranged so that sandbags of known weight are lifted by contraction of the group of muscles under investigation The greatest weight that can be lifted fifteen to twenty times in one exercise may be accepted as an arbitrary measure of muscle efficiency and this is charted week by week in the form of a graph [2]

Types of remedial exercise—Two systems of remedial exercise are to be distinguished 1) the Danish system [1] of free-swinging movements *designed* to promote suppleness and agility 2) the Swedish system [3] of controlled and resisted exercises planned for the redevelopment of weak muscles In the rehabilitation of an injured patient both types of exercise should be employed The free swinging movements of gymnastic and recreational activity are necessary to restore general fitness poise and agility, to accelerate reaction time and to promote mental alertness On the other hand muscle

Knudsen, K. A. "A Textbook of Gymnastics." London: J and A. Churchill, 1937
Nicoll, E. A Rehabilitation of the Injured. *Brit. med. J.*, 1941, 1, 501
Arvedson, J The Technique, Effects and Uses of Swedish Medical Gymnastics and Massage. London, J and A. Churchill, 1937

within a few minutes Even despite the handicap of plaster his gait should be almost indistinguishable from normal

Correcting habit-limp—If a limp is already established it may corrected by insisting on equal stride equal timing and an upright posture at the same time checking out toeing a stiff knee gait or any oth... individual limp If the habit is firmly ingrained it can be broken more easily by analysing gait into its component movements and exaggerating each of them With the surgeon or doctor walking alongside demonstrating and supporting him, the patient performs a series of isolated movements. The left hip and knee are flexed to the right angle, the knee is extended and the heel is put to the ground a few inches in front the left toe is put to the ground and the right heel raised the right hip and knee are flexed to the right angle and so on Gradually with steady rhythm, the movements are performed more quickly until they fuse into a normal gait

Teaching to run—In recent years I saw a patient whose ankle joint had been arthrodesed two years before for a comminuted fracture-dislocation sustained eighteen months earlier He was an intelligent and co-operative man The arthrodesis had relieved all pain He had learned to walk without a limp, he could easily walk eight or ten miles There was no circulatory disturbance or œdema he had gone back to work. And you run ?" I inquired Oh no he said, I can t run I nearly missed the train this morning because I couldn t run There was no physical reason for his inability to run but nevertheless he was unable to run I took him by the arm and we marked time together Then we did it on tiptoe We increased the pace and when we were going steadily we moved forward an inch with each step Gradually the step was lengthened and within a few minutes a grateful and very astonished man was running normally

Teaching to mount stairs—Many patients solve the difficulty of mounting stairs by arranging a bedroom on the ground floor and generally disorganising their household There may of course be good reason for the difficulty With a stiff hip joint it is easier to go upstairs backwards than forwards With a wasted quadriceps the difficulty is in going downstairs With weak calf muscles the problem is to get the whole foot squarely on the step But whatever the difficulty it must be solved, and it is the surgeon s duty to solve it Special exercises should be arranged, and there must be tuition on a test flight of stairs constructed in the gymnasium with two handrails to give confidence and steps of varying depth to increase skill

Teaching to jump—During the last great war a pilot baled out and sustained a severely fractured foot Movement was painless, the muscles regained strength and there was no swelling or œdema He learned to stand on tiptoe to walk and to run and it seemed that recovery was complete But he was unwilling to resume duty He was a first-class type of man and the explanation was not obvious—until we followed his chain of reasoning His foot had been fractured by a jump surely it could not stand another supposing he had to bale out again! So we taught him to jump into a sandpit first from twelve inches then from two feet and finally from the eight or ten feet which corresponds to a parachute drop His confidence was restored and he at once went back to duty Every workman who falls from a height and sustains a fracture of the calcaneum

FIG 1600

Treatment by special exercises

The fixed bicycle forearm exerciser ankle exercisers, weight lifting exercise for thigh, static exercise for spine in plaster and pulley weight exercise for spine out of plaster are all resisted exercises.

tibia or spine may develop a similar fear Jumping exercise should be part of rehabilitation

Rehabilitation after amputation—Amputation is the beginning and not the end of treatment [1] It is the surgeon's duty not only to secure shrinkage of the stump and redevelopment of the muscles but also to arrange for the fitting of an artificial limb to be sure that the patient uses his limb that he walks without a limp and that he has no fear of stairs irregular surfaces or cambered slopes. The basis of retraining [2] is 1) to develop muscle control and central co-ordination by which the stump—and therefore the artificial limb—is reconnected with the brain, 2) to teach balance forward swing of the limb without abduction and control of extension of the artificial knee

Muscle control and cerebral co-ordination—In a mid thigh amputation the extensor and adductor muscles of the hip must be strengthened. The extensor muscles are important because they control extension of the artificial knee The adductor muscles are important because they have been damaged at the time of amputation by removing half the insertion To develop the extensor muscles the patient stands with a pulley and weight in front, and a sling passed round the back of the stump to develop the adductors he turns sideways and fixes the sling over the inner surface of the stump He must also develop agility and impulsive action He must overcome the tendency to feel that the stump does not belong to him Simple games are advisable such as football with a soft ball which is kicked by the stump Swimming is an excellent activity and other recreations may be planned by which the limb is reconnected with the brain

Teaching to walk after amputation—Three exercises are taught before any attempt is made to walk 1) balance 2) swinging the limb without abduction 3) making a mark. Body weight is balanced on one foot with every normal step and the first task after fitting an artificial limb is to acquire balance The patient stands supporting himself with his outstretched hands on the shoulders of an instructor The sound limb is lifted from the ground, at first momentarily and then for longer periods Practice is continued until he is capable of the final and supreme test of standing on the artificial limb without support and with the normal limb flexed to a right angle at the hip and knee joints He must then learn to swing the limb without abducting it at the hip joint An outward swing with every step is the characteristic gait of an untrained patient with a mid thigh stump It is the result of overaction of the abductor muscles half the adductor muscle insertion having been removed. The patient must therefore stand on the normal limb and swing the artificial limb to and fro deliberately contracting the adductor muscles with each forward movement Exercise is continued until the new co-ordination of muscle activity becomes automatic and subconscious He then learns control of extension of the

[1] An elective amputation is not justified at all unless after-treatment has been planned to a conclusion. One of the greatest mistakes I ever made was to re-amputate a Syme's stump without first investigating the question of financial resources and supply of artificial limbs. The patient had to rely upon a second-hand prosthesis and although the below-knee stump was surgically excellent the functional result was deplorable It would have been better to have left him stumping about on his Syme amputation. A good stump with a bad artificial limb is even worse than a bad stump.

[2] These notes on rehabilitation after amputation are based on the experience and teaching of my friend Perkins. They are compiled from notes of his lectures contributed regularly to my fracture course British Post-graduate Medical School. For further details the reader is referred to his excellent "Amputations and Artificial Limbs." Langdale-Kelham, R. D., and Perkins, G. London Oxf Manuals, 1942.

groups which have been injured and are wasted by immobility regain strength more rapidly by resisted exercises A clinical investigation by Flight-Lieutenant Doran[1] of a series of upper limb injuries treated in a busy rehabilitation centre illustrates clearly the rapid recovery of muscle strength under a regime of resisted exercise and the slower recovery when free movement alone is employed (Figs 1601 1602) A muscle hypertrophies in accordance with the demand made upon it, and graduated exercise against an increasing load is the scientific method of regaining muscle power But an overdose of this medicine is poisonous To sit on a bench hour after hour, lifting sandbags suspended from pulleys is one of the deadliest and most soul-destroying activities It must not be pursued to the point of boredom It is better to regain muscle power slowly in a happy patient than

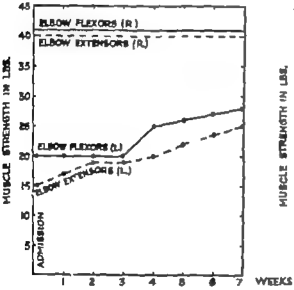

Fig 1601
Treatment by free exercises.

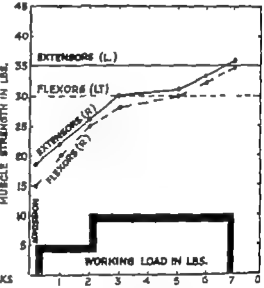

Fig 1602
Treatment by resisted exercises.

Muscle efficiency charts in two cases of fracture of the shaft of the humerus showing more rapid recovery of powers by resisted exercise (Fig 1602) than by free movements (Fig 1601).

to regain it rapidly in a miserable one Constant change of activity is necessary The same exercise must be done in many different ways and every form of treatment should be employed resisted exercise static exercise pulley and weight exercise free-swinging exercise recreational exercise occupational exercise exercise after massage and electrotherapy

Resisted exercise—A resisted exercise for the quadriceps muscle may be performed by extending the knee against pressure by the hand of a masseuse against a weight suspended over the ankle or against the resistance of a sandbag and pulley But resisted exercise can also be performed by the patient's unaided static contraction

Static exercises—When a patient fixes a joint and strongly contracts his muscles resistance is offered by the opposing group of muscles This is the basis of quadriceps drill The muscles are not just flickered—they are contracted they are contracted more strongly they are contracted

[1] Doran F S A. Personal communication.

artificial knee Whereas the normal knee is extended by the quadriceps muscles the artificial knee must be extended by putting the heel to the ground and pressing the thigh back by extension of the hip The patient is reminded of his Rugby football days and taught 'to make a mark. Finally he walks with the aid of two sticks but never with one stick. He must take short steps of equal length and equal timing, he must stand upright and not look at his feet

Teaching to go up and down stairs—Stairs are to be mounted one at a time the normal limb leading In going down stairs the artificial limb leads The patient must remember to keep the knee braced back into extension and he may find this easier if he leans slightly forwards

Fig 1606

Rehabilitation in hospital wards

Medicine ball in the solarium. Here there is no lethargy and despair but only activity and life

REHABILITATION IN HOSPITAL WARDS

It cannot be emphasised too often that rehabilitation is not convalescence it is not even convalescence of an active type It is a measure of treatment comparable in importance with reduction and immobilisation of the fracture and which begins at the same time From the earliest stage of treatment every phase of rehabilitation must be practised—psychological treatment social service muscle development joint mobilisation and diversional therapy Sisters nurses and masseuses must be specially trained in the art of knowing what to say and what not to say to a patient Almoners and social service workers must be busy from the day that the patient is admitted Matrons must be concerned with the exercises of a patient even more than with the neatness of his bedclothes Surgeons must forget their dignity they must take off their coats Every member of the staff and every patient must be inspired with optimism and cheerfulness There must be

secretaries clinical photographers and rehabilitation orderlies were trained on a uniform plan Case sheets including detailed typewritten progress notes and prints of all important radiographs were interchanged between one centre and another in accordance with the movement of the patient The surgeon who began treatment was informed of subsequent progress and the end result, and there was a follow up review six months after the completion of treatment Medical officers were interchanged between mobile receiving centres orthopaedic centres and rehabilitation centres There was continuity of treatment, not by an individual but by a concerted team of experts The value of organisation was proved by the results Despite the frequency of multiple injuries often of appalling severity and with gross contamination of wounds, less than 5 per cent of patients were invalided The incidence of non union in one series of nearly 15 000 compound and closed fractures was 0 per cent and the amputation rate was 0 1 per cent No less than 85 per cent of air crew members with major injuries regained a flying category and the late follow up review showed that 8 22 per cent did in fact resume operational and flying duties

ORGANISED FRACTURE SERVICE

The four essentials of an organised fracture service are 1) segregation of patients 2) continuity of treatment 3) daily supervision of treatment 4) unity of control

Segregation of patients—Activities in the wards of the hospital in the out patient department in the massage rooms and in the rehabilitation department are all phases of one continuous treatment There must be no break in continuity there must be no transference of the patient from the control of one staff to that of another One staff, under one control and pursuing one system of organisation should be responsible for treatment from the first day of injury to the last day of recovery It is obvious that segregation into a single department which controls both in patient and out patient treatment is essential No patient must escape from the invariable routine of organisation

Subsections of fracture department—*Massage gymnastic and x ray sections*—The massage gymnastic and rehabilitation departments should be subsections of the fracture department Similarly a section of the x ray department of the hospital should be included within the organisation of the fracture department This section affords a twenty four hour service facilities for the reduction of fractures under x ray control and for the rapid examination of patients throughout the time that daily and weekly clinics are being conducted It should be situated in such proximity to the fracture clinic that the patient cannot lose himself on his way to and fro It must be designed and organised to serve the requirements of the fracture department rather than the requirements of the rest of the hospital

Routine fracture clinics—*Daily clinic*—The need for daily supervision of treatment is obvious Fractures are radiographed reduced and immobilised within a few minutes of arrival at hospital whether by day or by night Every fracture treated during one twenty four hour period must be reviewed the next morning at the daily fracture clinic and on every subsequent

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Fig 1606

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morning until perfect reduction has been achieved, until the danger of early complications is passed and until the practice of active exercises is well established

Weekly clinic—If the daily clinic is not conducted by the surgeon in command but by one of his assistants there must be a weekly review clinic at which every new case treated during the previous week is examined, and treatment reviewed The patient is then referred to the weekly follow up clinic at which attendance is continued until recovery is complete

Six monthly follow-up clinic—Invaluable information is often gained if patients are re-examined six months or longer after the cessation of all treatment When the patient is discharged from treatment he is given a warning note that he will be sent for his name is entered in a diary and six months later he is asked to attend an evening clinic This is held one night a week to re-examine all patients discharged in the corresponding week, six months earlier Patients who fail to attend are written to again, and asked to fill up a questionnaire

Case records—The case record must include the emergency notes of the surgeon who first sees and treats the patient and notes dictated on every occasion when the patient is examined or treated, whether in the ward, in the fracture theatre in the fracture x ray department in the daily or weekly fracture clinics, or in the massage and rehabilitation departments Prints of all radiographs should be included in the record which must follow the patient throughout every phase of his treatment

Patient s instruction card—If a patient misunderstands his instructions, and reports after a delayed interval of a week or two the opportunity for correcting deformity and preventing stiffness of joints may have passed. It should always be assumed that a patient may misunderstand, and his instructions should be in writing A card bearing the case reference number should be handed to him with the date of the next attendance stamped upon it At the weekly review clinic the new attendances of the previous week are checked and a note is sent to each patient who fails to report On the patient s card should also be printed an instruction that when plaster has been applied the limb should be kept elevated and that if the fingers or toes become blue or white or movement is lost the patient must return to hospital at once whatever the hour of the day or night

Structure of a fracture clinic—The three essential units of a fracture clinic building are the examination room, the fracture theatre and the x ray room These rooms should be arranged in the closest possible proximity in such a way that the patient cannot mistake his instructions Whether a fracture is being reduced for the first time remoulded after an interval or replastered at a subsequent date the same routine is always followed namely examination manipulation x ray re-examination, remanipulation re x ray and so on The rooms are correspondingly arranged in a closed circuit

$$\begin{tikzcd}
 & \text{Examination Room} \arrow[dl] & \\
\text{Fracture Theatre} \arrow[rr] & & \text{X ray Room} \arrow[ul]
\end{tikzcd}$$

no lethargy and no despair only activity and life The accident ward should be the happiest place in the hospital Judicious use should be made of the wireless and piano singing should not be limited to Sunday hymns Every patient must co-operate in treatment and be interested in occupational pursuits Dart boards, tenniquoits and billiards should not be far away Concerts and film shows should be arranged The clinical secretary must do her share by a cheering smile and a kindly word Orderlies, porters and ward maids must share the spirit of happiness

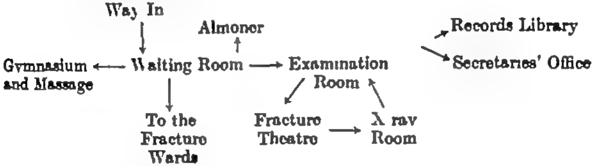
The importance of work—It is necessary not only to dismiss fear and depression, to create an atmosphere of cheerfulness, and to cultivate the will to recover, but also to emphasise the importance of hard work The

FIG 1607
Rehabilitation in hospital wards
Patients playing quoits in the convalescent room.

dominant note of treatment must be work, not amusement Valuable as diversional therapy is it must not divert the patient from his task Every patient in the ward has at least one special exercise to perform The man with the fractured forearm exercises his fingers and prevents stiffness of the shoulder The patient with the fractured tibia moves his toes and strengthens the thigh muscles later he develops the calf by pressing against the sole of the plaster Every patient in a hip spica practises quadriceps drill If it is a double spica he turns on one side to mobilise the knee joint which is free The man with the fractured spine turns on his face and develops the erector spinæ muscles Every patient with a knee-joint disability learns quadriceps exercise before operation and practises it immediately afterwards Limbs that are not injured are also exercised in order to promote general fitness and reduce difficulties which will arise when weight-bearing is resumed

It should be impossible for the patient to escape the routine After manipulation he must not leave before the position of the fracture is checked by x ray Furthermore when the x ray has been taken he must return for re-examination The fracture theatre should therefore open directly from the examination room and lead directly into the x ray room, which in turn leads back to the examination room and not to an exit corridor

To this basic structure must be added the ancillary services The secretaries office and records library must open from the examination room the almoner s office from the waiting room and the gymnasium and corridor to the fracture wards also from the waiting room The completed clinic may be represented as follows —



It is on this plan that the Liverpool Royal Infirmary Fracture Clinic was built A model of the clinic is shown in Figure 1011 and a photograph of the examination room in Figure 1012 The efficiency speed of working and relative freedom from error which proved possible in this department were in striking contrast with the difficulties delays and misunderstandings on the part of patients which characterised the working of the older department when the units were scattered in various parts of a large hospital

ORGANISED ACCIDENT SERVICE

Much has been accomplished in the development of organised fracture services But this is the beginning and not the end General accident services must now be organised A comprehensive service must embrace the treatment not only of fractures but also of soft-tissue injuries infections of the hand burns tendon and nerve injuries and indeed all injuries of the locomotor system [1] This was foreshadowed in the report of the Delevigne Interdepartmental Committee We have little doubt that the principles of continuity of treatment and after-care until working capacity has been restored should be applied in the accident departments of hospitals to the treatment of all injuries entailing disablement We believe that the results of organised fracture treatment will lead to the adoption of similar measures for dealing with other disabling injuries Soft tissue injuries are no less incapacitating than fractures they are no less serious in their influence on industrial production and future earning power and because numerically they outnumber fractures in the proportion of five or ten to one the problem they present is much greater Too often in the past the casualty surgeon was the last appointed and often the most junior resident He was given the responsibility of treating wounds lacerations

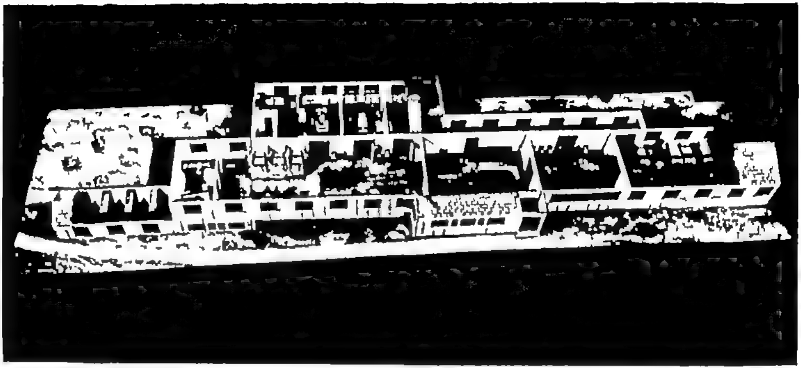
[1] British Orthopaedic Association, "Memorandum on Accident Services. *Lancet* 1943 1 520.

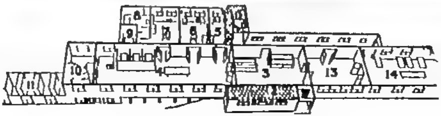
Exercise-leader and rehabilitation orderly—If the exercise is to be of value it must be repeated over and over again and practised hour by hour The first five minutes of every hour should be earmarked for special exercise Much is to be gained by appointing one patient as the exercise leader if he is of the right type eager enthusiastic and with qualities of leadership other patients are inspired by his example But this is not enough Each individual must be trained his special difficulties must be overcome he must be encouraged urged coaxed and driven One member of the staff should therefore be appointed to each fracture ward as the rehabilitation orderly or as he was known in one hospital where I worked as the muscle mechanic It may be wise to select a masseuse or medical gymnast or alternatively a specially trained nursing orderly who is experienced in physical training and can also assist in plaster work. Whoever is chosen must accept the full time duty of instructing in special exercise supervising hourly practice teaching walking and correcting limp encouraging occupational therapy organising competitions and games exercising patience and good humour, and generally promoting an atmosphere of enthusiasm

Rehabilitation in the out-patient department—In the case of sedentary and light industrial workers it is often possible for treatment to be completed within the precincts of the hospital. Rehabilitation, which was begun in the ward is continued in the out-patient department A large gymnasium is necessary and there must be gymnastic and recreational equipment including medicine balls light balls, nets for deck tennis and volley ball skittles pulleys and weights and the less complicated types of occupational therapy Masseuses medical gymnasts, physical training instructors and occupational therapists work under the instruction of the surgeon. The patient should attend for several hours each day and if possible a midday meal should be provided so that the whole day may be devoted to the task. Getting fit is a whole time job

REHABILITATION IN SPECIAL CENTRES

If the patient is more seriously injured or if he must return to heavy industry treatment cannot be completed satisfactorily in a city hospital If space is confined exercise must be static Greater interest and enthusiasm can be secured by the exercises of movement—running skipping cycling swimming It is therefore an advantage from the purely physical point of view that treatment should be completed where there are playing fields and swimming pools bowling greens and croquet lawns football grounds and cricket pitches But there are more subtle reasons for the development of rehabilitation centres remote from city hospitals Open air and a change of surroundings are no less important than good food and recreations Moreover the average man who lies in bed for weeks and months asking for this ordering that commanding the other becomes the king of a little universe which revolves around him The germ of chronic invalidism is easily implanted A new discipline and a new mode of life are necessary The hospital atmosphere must be avoided The patient must be inspired by a new spirit of enthusiasm he must be removed from the influence of over indulgent relatives His whole life must be controlled and adjusted and this is possible only when sleeping quarters recreation





1 Out-patient entrance.
2, Almoner's office.
3, Waiting room.
4 Examination room.
5, 6, Twin fracture theatres.
7 X ray room.

8, Dark room.
9 Film drying room.
10 Secretaries' office.
11 Records filing library.
12, To the fracture wards.
13, 14 Gym and massage rooms.

FIG. 1611

PLAN OF LIVERPOOL ROYAL INFIRMARY FRACTURE DEPARTMENT

FIG 1008

Rehabilitation in special centres

Part of the day is spent in hard work—whenever possible out of doors.

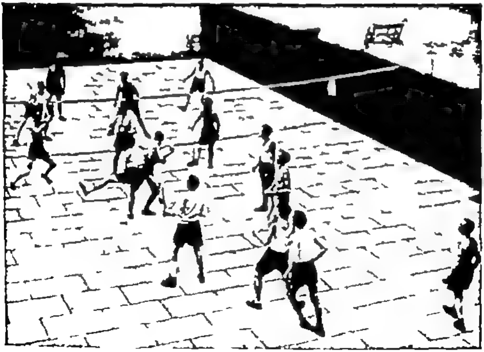


FIG 1009

Rehabilitation in special centres

The rest of the day is spent in recreations—volley ball is useful for every type of injury

FIG. 1012

Examination room of fracture clinic showing couches on the left, x ray viewing box between each couch, wet film carrier in foreground, screened cubicles in background, and twin fracture theatres and x ray room opening directly on the right

rooms, gymnasiums playing fields and swimming pool are included within a compact and self-contained unit Although the rehabilitation centre should be geographically apart from the parent hospital there must be continuity of treatment by the same surgical team Treatment in the centre must be supervised by a medical officer A patient who is embarking upon a course of strenuous activity must have supreme confidence in the surgical judgment of his adviser No physical training instructor is in a position to reassure a patient that certain symptoms may be ignored and that activity should continue despite discomfort This reassurance is needed at the moment when symptoms arise and not once or perhaps twice a week on the occasion of routine medical inspections. The medical officer must work in the gymnasium, on the playing fields, in the swimming pool, side by side with the patient, spending half an hour an hour or even several hours in the handling of one individual, becoming personally acquainted with him searching for his particular difficulties, dealing equally with psychological and physical handicaps explaining his problems anticipating his fears, reassuring his mind giving him confidence and completing his treatment

FIG 1610

Milk bar in the gymnasium

In a corner of the gymnasium is a home-made milk bar decorated by the patients. Between periods of strenuous activity milk shakes and flips are in steady demand.

and soft tissue injuries unguided and unaided by senior members of the visiting staff Young and inexperienced surgeons who would hesitate to remove an appendix or even to inject a varicose vein accepted the far more difficult and critical task of treating wounds of the fingers and hand and suturing severed nerves and tendons Casualties attended hospital in their thousands for daily dressings, with no close supervision of progress, no attempt to graduate activity no organisation of after-care and no semblance of rehabilitation The challenge has now been accepted and most centres of surgery have well organised and fully supervised accident departments. The Royal College of Surgeons of England now insists that a young surgeon should in addition to other training work in such a department for six months before he can even sit for his final fellowship examination.

Planning of an accident service—Five components of a complete accident service must be recognised

Casualty reception
↓
Wards
↙ ↘
Fracture follow up | Wound follow up
↘ ↙
Rehabilitation

Casualty reception unit—We must dismiss for ever as a horrible memory the practice which was so general of allowing casualty cases to sit on hard forms in a row surrounded by wailing relatives bleeding patients violent drunks and even dead bodies waiting their turn to go into a cramped space where they sat in a chair while wounds were stitched often within sight and always within sound of others whose septic fingers were incised, teeth extracted fractures manipulated, and stomach contents evacuated [1] The casualty reception departments of general hospitals were a disgrace to an honourable profession Whether the patient arrives by ambulance by car or on foot he is admitted direct to one of a series of resuscitation cubicles where he at once lies down is undressed and examined, and treated for shock. Relatives are accommodated in a comfortable waiting room where a cup of tea is available while particulars are taken and the almoner begins her work. Each cubicle is fitted with dressings a small sterilliser drug cupboard and blood transfusion apparatus In all but minor injuries a fifteen minute blood pressure chart is kept [2] If transfusion is needed the apparatus is fixed to the trolley and moves with the patient through radiographic

Incredible as it may sound, I assure the reader that this is no exaggeration. It is a precise picture of what was, until recent years, customary practice in the casualty departments of many general hospitals.

Blood pressure and shock— "The essential underlying factor in the production of the shocked condition is a prolonged and progressive fall in blood pressure" Fraser John. *Brit J Surg* 1923, 11 421. Surgeons must no longer put their fingers on patient s wrist, assume a learned expression, and pronounce the patient fit or unfit for operation. It is pure self-deception to think that the degree of shock can be estimated in this way The only reliable test is the blood pressure and a chart which shows whether the pressure is being maintained or is falling. If it is already as low as 90 mm. or less, blood transfusion should begin at once. Even if it is in the region of 140 or 160 mm., if the fifteen minute chart shows that it is falling, transfusion of blood should be started Shock is often accompanied by a temporary rise in pressure followed by a rapid and sometimes fatal fall

CHAPTER XXXVI

ORGANISATION OF AN ACCIDENT SERVICE

No London policeman ever went back to full duty after a Pott's fracture—this I was taught as a medical student less than thirty five years ago. It was believed that some degree of permanent disability was the inevitable sequel of nearly all fractures. Mal union and non union were accepted as unavoidable complications. In a series of 3 000 fractures investigated in 1912 by a British Medical Association Committee [1] no less than 1 276 were mal united, and even when the 'anatomical result' was good, the 'functional result' was often poor. It is difficult for a surgeon practising in 1955 to believe that mal union could ever have been accepted in 40 per cent of fractures, or that there could ever have been discussion on the relative merits of 'anatomical results' which ignored function, and 'functional results' which ignored form. Nevertheless Hey Groves wrote in 1916: "These results form an authoritative standard by which all subsequent fracture work can be measured and with which it can be compared." By the time another B.M.A. fracture committee had been appointed in 1934 [2] statistics were available from the organised fracture services of the Liverpool and Manchester Royal Infirmaries which showed that permanent disability could be avoided in over 95 per cent of fractures. Some surgeons were critical, some were incredulous, but in general the report was accepted. It had a most striking and far reaching effect. Leading industrialists recognised the importance of the problem. Trade union organisations were interested. The Industrial Welfare Society became active. The Government appointed an Interdepartmental Committee. Hospital staffs accepted the challenge. Fracture clinics developed throughout the country. The standard of fracture treatment was rapidly raised. Mal union and non union almost disappeared. Surgeons no longer debated anatomical *versus* functional results; the new object of treatment was a limb clinically indistinguishable from normal; they were satisfied only when function and form were both perfect, and indeed only when the patient himself was satisfied that they were perfect, for that is the supreme test.

This high standard cannot be achieved by surgical skill alone. The treatment of fractures differs from other branches of surgery where success or failure depends upon the technique of an operation. The most excellent primary treatment of a fracture is worthless if equally expert treatment is not continued for many weeks or months afterwards. The after treatment may indeed be more important than the primary treatment. Complications

[1] Fracture Committee Report. *Brit. med. J.* 1912, 2, 1505.
[2] Report of British Medical Association Committee on Fractures. *Brit. med. J.*, 1935, 1, 306.

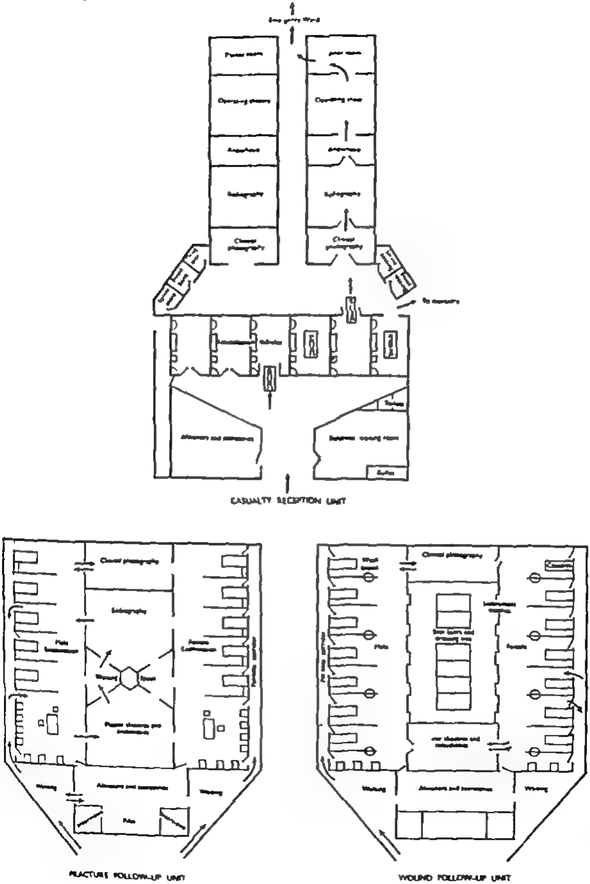


FIG. 1613

Plan of a comprehensive accident service showing casualty reception unit, fracture follow up unit, and wounds and burns follow up unit.

must be avoided Tight plasters must be split before circulatory failure causes ischæmia and paralysis Swelling of fingers and toes must be prevented Joint stiffness must be treated before it develops The patient who fails to exercise must be singled out seen day by day, and stimulated into activity Redisplacement of fragments must be guarded against and frequent check radiographs taken The position of fragments may need to be adjusted plasters wedged and new casts applied when swelling subsides After many weeks success may still be turned to failure by premature removal of the plaster and even when the fracture is firmly united the result is not finally assured There must be control of recurrent œdema redevelopment of muscles and mobilisation of joints Patients must be taught to walk, run and jump Constant supervision must be maintained until function is normal and confidence is regained

Importance of organisation—The chain of treatment obviously consists of many links the breaking of any one of which may cause failure Organisation is imperative The system which was universal till a comparatively recent date by which fractures were treated in general surgical wards under general surgical routine was gravely defective [1] The results were often disastrous not because surgeons were lacking in skill but because skill was not available to the patient at the moment when it was most required The brilliant success of careful organisation of fracture treatment was proved by Sir Robert Jones in the war of 1914-18 It was proved by the B.M.A Fracture Report which showed that indifferent treatment and lack of organisation may be responsible for increasing the incapacity period of fractures of the wrist from seven weeks to twenty nine weeks and of fractures of the ankle from eleven weeks to forty-seven weeks for increasing the incidence of permanent disability from less than 5 per cent to over 35 per cent and for tremendously increasing the financial loss to the community The importance of organisation was acknowledged by the Delevigne Interdepartmental Committee [1] which reported that the most authoritative surgical opinion of the country is agreed in recommending the institution of special fracture services Finally the merit of organisation was proved in the World War of 1939 45 Orthopædic and accident services have been developed in the Emergency Medical Service and in the military medical services of the Royal Air Force the Army and more recently the Royal Navy

Organisation of orthopædic and accident service in the Royal Air Force—Within a few months of the outbreak of the last great war an orthopædic and accident service was developed in the Royal Air Force Medical Service Orthopædic centres were developed and specially equipped Arrangements were made for the prompt transfer of injured air crews The number of centres increased with the demand until there were sixteen in England Wales and Scotland many with associated rehabilitation units and all served by four major rehabilitation centres This was the first comprehensive rehabilitation service to be introduced in this country The orthopædic and rehabilitation centres were staffed by teams of specialists experienced in general surgery and trained in orthopædic and traumatic surgery, aided by two consultants who examined all patients at regular intervals Clinical

[1] Report of Interdepartmental Committee on the Rehabilitation of Persons Injured by Accidents. H.M. Stationery Office Interim Report, 1937 Final Report, 1939

photographic and anæsthetic rooms to the emergency theatre These rooms should be arranged *en suite* preferably one set on each side of a central corridor so that infected wounds requiring drainage and recent contaminated but not infected wounds requiring excision are granted separate x ray anæsthetic and theatre facilities

Wards—The emergency ward divided into separate cubicles is the last part of the casualty reception unit Wounds of the fingers and hand, and crush fractures of the toes should be admitted To send such patients home causes unnecessary hardship and may add many weeks or months to the disability period by delaying the treatment of early complications After twenty four to forty-eight hours patients who need a longer period of in patient treatment are transferred from the emergency ward to one of the routine wards

Fracture follow-up unit—The organisation of the fracture follow up unit has already been outlined It must have its own radiographic and plaster rooms, independent of the facilities of the casualty reception unit which must be capable of working throughout the twenty four hours without interruption The same suite of rooms used for fracture follow up may however be used for orthopædic out patients on one two or three sessions a week.

Wounds and burns follow-up unit—A separate unit should be developed for the follow up of soft-tissue wounds of the fingers, hands and limbs The flow of patients is still greater than in the fracture unit Special facilities are needed for dressing sterilisation and the handling of many hundreds of patients without cross infection from one to the other

Rehabilitation unit—Final rehabilitation in the out-patient department of the hospital or in the special rehabilitation centre should be planned as already described in earlier pages

secretaries clinical photographers and rehabilitation orderlies were trained on a uniform plan Case sheets including detailed typewritten progress notes and prints of all important radiographs were interchanged between one centre and another in accordance with the movement of the patient The surgeon who began treatment was informed of subsequent progress and the end result and there was a follow up review six months after the completion of treatment Medical officers were interchanged between mobile receiving centres orthopaedic centres, and rehabilitation centres There was continuity of treatment not by an individual but by a concerted team of experts The value of organisation was proved by the results Despite the frequency of multiple injuries often of appalling severity and with gross contamination of wounds, less than 5 per cent of patients were invalided The incidence of non union in one series of nearly 15 000 compound and closed fractures was 0 per cent and the amputation rate was 0 1 per cent No less than 85 per cent of air-crew members with major injuries regained a flying category and the late follow up review showed that [illegible] 22 per cent did in fact resume operational and flying duties

ORGANISED FRACTURE SERVICE

The four essentials of an organised fracture service are 1) segregation of patients 2) continuity of treatment 3) daily supervision of treatment 4) unity of control

Segregation of patients—Activities in the wards of the hospital in the out patient department, in the massage rooms and in the rehabilitation department are all phases of one continuous treatment There must be no break in continuity there must be no transference of the patient from the control of one staff to that of another One staff under one control and pursuing one system of organisation should be responsible for treatment from the first day of injury to the last day of recovery It is obvious that segregation into a single department which controls both in patient and out patient treatment is essential No patient must escape from the invariable routine of organisation

Subsections of fracture department—*Massage, gymnastic and x ray sections*—The massage gymnastic and rehabilitation departments should be subsections of the fracture department Similarly a section of the x ray department of the hospital should be included within the organisation of the fracture department This section affords a twenty four hour service facilities for the reduction of fractures under x ray control and for the rapid examination of patients throughout the time that daily and weekly clinics are being conducted It should be situated in such proximity to the fracture clinic that the patient cannot lose himself on his way to and fro It must be designed and organised to serve the requirements of the fracture department rather than the requirements of the rest of the hospital

Routine fracture clinics—*Daily clinic*—The need for daily supervision of treatment is obvious Fractures are radiographed reduced and immobilised within a few minutes of arrival at hospital, whether by day or by night Every fracture treated during one twenty four hour period must be reviewed the next morning at the daily fracture clinic and on every subsequent

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[1] Report of Interdepartmental Committee on the Rehabilitation of Persons Injured by Accidents. H.M Stationery Office Interim Report 1937 Final Report 1939.

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